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SCIENCE AND THE MECHANIC ARTS

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AMERICA'S AIR SERVICE.*

BY

W. F. DURAND, Ph.D.,

Chairman, National Advisory Committee for Aeronautics.

THE purpose developed in May and June last looking toward the development by the United States of a great air fleet as one of its chief contributions in the world war met with instantaneous response in the heart and in the imagination of the American people.

The bill which was prepared and which was intended to put into effect the first stage of this great program passed Congress by a well-nigh unanimous vote and almost without discussion. Probably never before in the history of Congressional legislation has a bill been accepted by the nation's law-makers with so little knowledge of the detailed estimates and precise measures contemplated. Certainly never before has any such sum ever been appropriated out of hand for a single agency of war.

The history of the development of the great movement thus authorized by Congress, in so far as it can now be properly made public, cannot fail to have some interest for the American people, and the following paper has been prepared for the purpose of rendering some partial account of the more intimate purposes of such a war measure and of the steps needful in their realization.

The possibilities of a great aerial fleet have, since the early

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days of the war, appealed vividly to hundreds of people, both within and without the military and naval services. It is, however, probably fair to say that it was not until the interchange of information and of views made possible by the visits of the Balfour and Viviani-Joffre commissions to Washington in May that the possibilities inherent in the operation of such a fleet, together with the possibilities of its actual realization, began to take definite shape in the minds of the military and naval authorities and their advisers.

When confronted with a scheme so far transcending all previous undertakings in magnitude, many vitally important questions press for answer. Thus:

1. Of the various types of machine—fighting, reconnaissance, bombing, and training—what number shall be set as a goal for active service at one time?

2. What shall be the technical characteristics, size, power, armament, etc., of the machines in these several types?

3. What wastage in such machines is to be anticipated?

4. In consequence, what numbers in each type must we be prepared to build within a twelve-month or any other specified time?

5. How many trained aviators will be required to maintain the desired number of machines in active service?

6. How many men must be put through preliminary training in order to secure the needful number of active aviators with the necessary reserves; or, in other words, how much raw material must be handled in order to secure the necessary amount of finished product?

7. How many mechanics and repairmen will be needed to keep this fleet of airplanes in all classes up to "concert pitch" and ready for instant service at any and all times?

8. Where and how are we to undertake to build the number of airplanes indicated as the necessary gross output, say for a year, in order to maintain the fleet continuously at proper strength? Or, put otherwise, we may perhaps well ask, What is the maximum number of airplanes which can be built in these various classes in the United States or by the United States without undue disarrangement of other needful war industries and of the irreducible minimum or civil industries?

9. To what extent will further demands be placed on our productive capacity by demands of our allies in Europe for air-

planes or engines in types which we may hope to produce with high economic efficiency, and to what extent may we expect to draw upon them for certain types—as, for example, the fighting scout—thus relieving the United States, to some degree, of attempting, at least at the start, to produce this final word in the evolution of fighting aircraft as developed on the battle-fields of Europe?

10. To what extent will the demands of our allies call for raw material, such, in particular, as airplane timber? Will the total demand exceed the presumable supply, and, if so, to what substitutes may we turn?

Immediately, answers to these questions are developed, even in approximate form, multitudes of further questions arise, some of which are of the most fundamental importance.

One of these is the question of standardization. To what extent shall an attempt be made to standardize the engine and plane, thus facilitating rapid and economic production, and to what extent shall several competitive types be employed, thus aiming at constant competition and evolution by a process of selection—the survival of the fittest? Advantages and disadvantages lie with either policy, and neither should be pushed to the extreme. Broadly speaking, the Germans, during the war, have adopted and worked consistently on the policy of a high degree of standardization and the limitation of the number of different types. Types or designs few in number and a consistent effort to improve and perfect those types or designs—such, in general, has been the German policy. On the other hand, the French and English have adopted a more open policy regarding the number of types and designs and have placed less importance on the economic results to be derived from close standardization.

Without attempting to define too closely the policy to be followed by the United States, it may be properly said that when a scheme so vast as that now under realization is in hand, economy of production becomes an imperative factor, and, to this end, some degree of standardization is necessary. On the other hand, the authorities responsible for the creation of this vast fleet do not intend to lose the advantage of competition and of the development and improvement which will come from a careful study of the results of actual service; and sufficient elasticity of program will be provided to permit of taking due advantage of the results of experience as developed in actual service over the fighting lines, and also to permit of the influx of new ideas and designs as fast as they may be able to demonstrate, under suitable trial, their superiority over the existing forms and designs.

It is a commonplace of economic production that the greater the number of units built from a given design the less will be the cost of production per unit. Again, at the start and for the first stage in the program of production, some one specific design must be accepted and placed in production for certain determined numbers. Beyond this, repetition orders may be given or changes introduced as experience may indicate. Here is demanded the most careful adjustment of various factors calling for the exercise of the best judgment which can be brought to bear on the many-sided character of the problem.

American flying boat.

Again, while speaking of the problem of standardization, it should be noted that, of the various types of machine, some are much more readily standardized than others. Thus the training or school machine is most readily standardized of all. Indeed, it is perhaps not going too far to say that this machine is already practically standardized for the English, Canadian, and United

States air forces. This does not mean that no further changes or improvements are to be expected in this type, but rather that the type as now approved seems, on the whole, to be so satisfactory as to justify production on a large scale and on a standardized basis and with the corresponding economy and production costs. On the other hand, the machines of the other types are more difficult of standardization, and the fighting or scout machine most difficult of all. This simply means that, with the changing developments over the battle lines and with the constant efforts of the enemy to improve his own machines, the program of design and production must be such as to permit, perhaps of rapid changes in form, proportion, power, speed, armament, and various other technical characteristics, in order that the machines in actual use over the lines may be as nearly as possible continuously responsive to the changing conditions to be met or to the improvements developed through scientific research or by inventive genius.

TYPES OF AIRCRAFT.

This will be perhaps a suitable point at which to speak briefly of the different types and forms of aircraft which have been developed under the urge of war conditions, and of the special purposes which they are intended to fulfil.

The principal types are:

1. Training machines.
2. Reconnaissance and artillery spotting.
3. Bombing.
4. Scout and fighting.

Training machines, so called, are intended to give the student aviator his first experience and training in the air. In the advanced schools of training, as referred to later, the candidate for aeronautic service is given further training in specialized types of machine, according to the character of service for which he may seem best fitted. In order, however, to develop confidence in the air and to learn the fundamentals of the art of flying, a machine is required of moderate speed, easy of manipulation, with good inherent stability and generally with the qualities suited to lay a foundation for further training in actual war machines.

For the very first stages and for familiarizing the candidate with the feel of the machine, with the nature of the controls, and with the first rudiments of the art, low-powered machines incapable of flying are used. Such machines are variously styled "grass-cutters," "penguins" (by the French), and various like descriptive terms. They are intended only to run along the ground, with perhaps an occasional short skim just above the surface.

With the development of some confidence and skill in managing the controls, more ambitious flights may be made, sometimes in a regular field training machine and sometimes in an intermediate type a little more advanced than the "grass-cutter."

For regular flights constituting full training, a machine of moderate size, weight, and power is required—typical weights ranging from 1200 to 1500 pounds, horsepower 80 or 90, and speeds of 70 or 80 miles per hour maximum.

For more advanced training, somewhat lighter machines with the same or higher power and comparatively higher speeds are employed.

Passing now to machines of direct military type, we find three chief functions to be fulfilled by such machines. These are:

1. Reconnaissance and artillery spotting.
2. Bombing.
3. Fighting.

In most cases, two or more of these functions are in some degree combined on one plane. That is, a reconnaissance machine should also be able to fight, likewise with a bombing machine, while the general duty of reconnaissance is always a part of the work of a machine in the air.

Nevertheless, the three types of function are measurably distinct, and the characteristics of the machine and its equipment are determined primarily in accordance with the function which is to be paramount.

Thus the primary function of the reconnaissance machine is observation and photography, and the characteristic machine of this type will carry two men, a pilot and an observer.

The two instruments for reconnaissance work are the human eye and the camera. The former is used for incidental and general observations, and especially for those which must be made available immediately to the higher command behind the lines. Such observations relate to the movement of troops, munition trains, supplies, the fall of shell, location of enemy's batteries, concentration of troops, etc.—in short, anything the immediate knowledge of which may be of value to the higher command.

The camera is used principally for purposes of map making, and especially with reference to the keeping of maps up to date with all information relating to the permanent structures of the enemy, trench lines, specially fortified positions, entanglements, dug-out openings, gun positions, munition depots, shell dumps, etc.

It is an interesting thought that through the human eye and wireless telegraphy information may be made immediately available to the command in the rear, and movements, changes, and formations described as they occur; while with the eye of the camera, and without the human brain to interpret the light stimuli received, the information hidden in the photographic plate or film must await development and printing before it becomes of direct use for military purposes. Both means of gathering and reporting information are, however, necessary. The camera cannot give results immediately available, while the eye, even in conjunction with the brain, cannot record with accuracy the many details needed for the preparation of adequate military maps. Thanks to improvements in photographic cameras for such purposes, it is now possible to prepare maps day by day, based on photographic records of the day, and have them ready for use within a few hours of the return of the plane bearing the exposed plates or films; and, thanks to the marvellous skill which practice in the interpretation of photographic records gives, it has been

Large Italian Caproni tri-plane.

found possible to determine with high precision the location and character of the defensive and offensive dispositions of the enemy in the way of permanent structures.

A word may perhaps be said here regarding the subject of camouflage—the disguise of strategic points or features of military structures, such as gun positions, dug-out exits, etc., in such manner as to make their detection difficult or impossible, especially from airplane photographs. Here, as elsewhere, we have a constant struggle between the defensive and the offensive—between the development of skill in the art of concealment and skill in the art of detection. They are developing measurably, perhaps, on even terms. Given time and suitable materials, many important strategic positions and features may, in the hands of skilful camoufleurs, be so disguised as to render their detection practically impossible by overhead photography. On the other hand, the scientific analysis of photographic printing in its relation to the objects photographed has proceeded to such a point that in the hands of a skilled interpreter of such photographs the most innocent and natural-looking features have been detected and identified in their true military character.

But to return to the reconnaissance machine. The primary purposes are, as we have seen, to report information of immediate significance and to gather photographic material for the correction and extension of military maps. To this end, the primary equipment needed comprises the observer, photographic apparatus, and a wireless outfit. The pilot flies the machine as low as anti-aircraft attack and other circumstances will permit, and the observer proceeds with his work. If attacked, the machine should have some means of offence, but its primary purpose is not to fight, but to gather information. It must depend primarily on the fighting machines which accompany reconnaissance machines to take the brunt of the fighting, to ward off enemy attacks, and to defend them from disturbance by the enemies' fighting planes. If attacked in force or outnumbered, it is the plain duty of such machines to make the best escape possible and return behind the home lines with such information as may have been gathered. Nevertheless, reconnaissance machines should be equipped with one or more machine guns in order that they may have some general means of offence in case of need.

Some further emphasis should perhaps be laid on the subject of artillery spotting as a function of this general type of machine. In fact, the machines allotted to this duty may perhaps be considered as a special group or section of the general type of reconnaissance machines. The importance of artillery spotting has been recognized from the first months of the war. The spotting machines hang aloft high in the air, circling about, watching the fall of shell from far-distant gun positions and sending, by wireless, information serving to correct the aim.

For the general purpose of reconnaissance and artillery spotting, machines of weight and speed intermediate between the bombing and the fighting machines are employed. Speeds of one hundred miles per hour and upward are typical of the general type of reconnaissance airplane.

Taking next the bombing machine, two types are recognized—the heavy and slow and the light and fast. The former are intended for night work, when the machine may fly lower and slower than for work in daylight, and may therefore be given a heavier load of offensive burden in the form of bombs; while the latter, for use without protection from the darkness, must be given higher speed and be capable of rising to heights above anti-aircraft range, and cannot therefore be given as heavy a load of offensive burden. Bombing machines usually carry two or three men, sometimes more, and have speeds of from 80 to 110 or 120 miles per hour. The special equipment of the bombing machine comprises the bombs, the apparatus for carrying and releasing them as desired, singly or in groups, and the aiming device. In addition, the bombing machine should carry one or more machine guns for general offence. The tendency will be presumably to increase the offensive armament of such craft, and we may anticipate a tendency toward more and heavier guns for offensive purposes on machines of this type.

But little can be said regarding the bombs themselves, the method of carrying and dropping them, or the aiming devices. These are matters over which a reserve must be drawn, for obvious military reasons. The interesting character of the problem to be met by the aiming device may, however, be briefly noted.

The airplane bomb is allowed to fall under gravity, which is, therefore, the only force acting to bring the bomb to the earth. It has, however, the velocity of the airplane at the instant of detachment, and hence will move in a path determined as the resultant of these two velocities—that gradually acquired under gravity and that due to the velocity of the plane. According to the well-known principles of mechanics, this would result in movement along a parabolic path, were no account taken of air resistance. Aside from the latter, therefore, observations must be taken which will determine the altitude of the plane at the instant of dropping and also the speed relative to the ground. With these known, the bearing of the target in a vertical plane can be determined at the instant when the bomb should be released in order to reach the target. A telescope may be set for this bearing, and when the target reaches the cross-hairs the bomb may be released. The realtive simplicity of this operation needs, however, supplementary correction to allow for the resistance of the air, due to which cause the path followed is not an exact parabola; also due to the drift of the machine under the influence of the wind itself, often variable between the plane and the ground. Again, the nature of these corrections varies according to the form and proportions of the bomb, so that for each design final corrections must be worked out by trial.

Italian reconnaissance plane.

After all this, it must be admitted that the target practice realized in bomb dropping is not, and cannot be expected to be, very close. From a height of 10,000 feet the time required for the bomb to fall under gravity is about one-half minute, and a very slight departure from the exact conditions when it is released may carry it wide of the mark at the ground. The only apparent way to realize effective work with bombs dropped from aircraft is either to fly low and reduce the errors of aim or to use planes in very large numbers, so that out of the hundreds or thousands of bombs dropped a fair number may be expected to find the military objective.

We come now to the fighting machine *par excellence*—the machines whose duty it is to protect reconnaissance machines in their work, to attack and drive away enemy fighters, to attack enemy reconnaissance machines in their work of spying out home defences or operations, and generally to serve as the fighting support of the reconnaissance machine in its work on the enemy's side of the line, and to attack and drive off the reconnaissance machines of the enemy or give battle to the fighting machines which may accompany them. In addition to this, fighting machines are being used more and more for direct offence in connection with drives against the enemy. The public press has carried many accounts of the use of aircraft in this manner, flying low and attacking trenches, reserve formations in the rear, and making themselves a significant and effective element of the offensive operation.

In the early months of the war aviators were armed with carbines or rifles as the chief arm of offence. These soon gave way to the machine gun as a vastly more effective agent. There are, in general two types of mounting, fixed and movable. In the former the gun is fixed to the machine and is aimed by aiming the machine itself. Practically all fighting airplanes are now of the tractor type, and this immediately raises the question of firing ahead with the propeller whirling directly forward of the nose of the machine. This problem has been solved in three different ways: (1) mounting the gun on the upper plane and firing over the propeller; (2) mounting the gun between the planes and firing through the propeller, with the shots so synchronized as to miss the blades themselves; (3) firing through a hollow propeller shaft driven by gearing from the main or engine shaft.

The first mode of mounting avoids all difficulty, so far as the propeller is concerned, but places the gun itself out of the ready reach of control of the pilot. The second mode of mounting has attracted much interest by reason of its novelty and boldness of concept. Originally due to Garros, it was quickly adopted and developed with improvements by both the Germans and Allies. The details of the arrangement vary, but depend usually upon some method of arresting or preventing fire at such instants as would bring the blade in the way of the bullet as it leaves the gun. The usual speed of fire of such guns is in the neighborhood of 600 shots per minute, and, since propeller speeds are usually twice that and more, it is readily seen that there can be allowed only one shot for about two revolutions of the propeller. There is, therefore, abundant chance for this shot to get through, if properly timed, without risk of piercing a blade. In case of delayed ignition the time relation may be deranged and blades are sometimes hit. As a rule, no great damage is done except to put a small hole in the propeller. In some cases, however, if the blade is in any degree shattered, further breakage might follow, with the result of throwing the propeller out of balance, loss of propulsive power, and probable disaster to the machine. The chances of such result are, however, remote, and pilots of fighting machines take no thought of any such contingency in connection with the other hazards to which they are subjected.

The third method of firing—through a hollow propeller shaft—avoids all need of synchronizing the gun with the propeller, but it requires a separate propeller shaft geared to the engine shaft. This, however, is coming to be, if anything, an advantageous mode of drive, due to the fact that, with propellers of the size suitable to absorb the horsepower required, the efficiency at high rotative speeds is poor. This is a fact well known in the mechanics of the air propeller and which cannot apparently be avoided. For the sake of high propeller efficiency, therefore, there is constant need to keep rotative speeds down. For the sake of a higher ratio of power to weight in the engine, there is a constant tendency to push rotative speeds up. So long as the propeller is carried directly on the engine shaft there is no way of reconciling these opposing tendencies. With an engine of the V-type, the propeller shaft may be comfortably located between the sides of the V, above the engine shaft and geared to it by appropriate reduction gearing. In this way any desired rotative speed may be given to the engine with any desired speed for the propeller, while the hollow propeller shaft provides a pathway for the bullets without danger of interference with the propeller blades. Each of these three modes of fixed mountings has its advocates and special adaptations. Only continued experience will serve to finally decide which, if any, will be the final approved form.

With the other general type of mounting, the gun is so carried as to permit swinging in azimuth and changing in elevation in such manner as to give a wide arc and range of fire, practically in all directions except where prevented by the parts of the plane.

Fighting machines are made in both the one-place and the two-place types. In the former the single pilot must both guide and fight his machine. In the latter the duties may be divided: either pilot may control the machine, and both are provided with machine guns for offensive use against the enemy. In this manner the machine is always under control so long as both pilots are not fatally or seriously injured.

American training plane.

Machine guns are of two general types. In one the gun is operated direct by the force of the recoil, while in the other the operating mechanism is actuated by gas under pressure drawn from the barrel a little back of the muzzle. Without attempting to specify too closely the machine gun arrangements in use by the Allies, a few typical arrangements used by the Germans may be mentioned.

In a large bombing plane, guns are mounted firing ahead, on either side and to the rear through a longitudinal tunnel under the length of the fuselage.

A fast fighting plane mounts three fixed guns firing ahead and converging at a point about fifty yards ahead of the plane.

Another fighting plane mounts a forward pivotal gun and a rear gun which may be depressed to shoot downward through a tunnel in the fuselage behind the pilot.

Other types mount two guns firing forward through the propellers by means of a synchronizing device.

Arrangements and mounts for machine guns on aircraft are undergoing rapid development and change, and the approved system of to-day may be to-morrow discarded for a more effective arrangement. Broadly speaking, the present tendency in airplane armament is toward more guns, heavier guns, and more effective all-round offence.

The chief military equipment of the fighting planes comprises, therefore, machine guns. The special problem presented by machine gun sights for use in aircraft can be only mentioned. Broadly, it is that of making due allowance for the speed of both airplanes in whatever direction in space they may happen to be going at the instant of fire. This becomes, in the general case, a most complex problem, involving rapid judgment in the use of the intricate form of machine gun sight which is intended to serve as a basis for its solution.

One simple case may be mentioned in order to show the deceptive character of ordinary observation. Suppose the machines are circling around a common centre at opposite ends of a diameter and at a speed of about 100 miles per hour or, say, 150 feet per second, and suppose that the circle is 1000 feet in diameter. Then as each pilot looks at the other there will be no change in relative position or attitude of the machine, and if, on the basis of this superficial observation, a point-blank aim were taken, the bullet would fly some 120 feet wide of the mark.

Such cases and many others still more complex must be met and quickly judged in the use of the machine gun firing from one airplane against another.

While thus some attempt has been made to classify and discuss the functions of the various types of airplanes used for military purposes, too much stress must not be laid on arbitrary classifications, which may rapidly become obsolete in the advancing art of airplane warfare. In particular, recent months have seen notable advances in the size of military aircraft, especially as illustrated by the Italian Caproni, the British Handley Page type, and the German Gothas. Such machines, often of 700 horsepower and upward and capable of carrying 10 to 20 men, may be used both for fighting or bombing, or, in fact, for any purpose which may be realized by the ability to carry great weights at fairly high speeds and including a considerable crew of men with offensive gun armament, both in number and calibre far in advance of the one or two conventional machine guns now carried as the typical airplane offensive armament. It should be said, however, that such machines are classed in the heavy bombing group.

With these remarks by way of reference to the general problems involved, we may advance a step nearer and examine more closely some of the specific problems which are met at the very start of the development of an actual program for the American air fleet.

First, the engine: What type or types of engine shall be used, of what horsepowers, what designs shall be employed, and in general what shall be the first step toward the development of the power plant of the airplane? It is perhaps well to note at this point that as between the engine and the plane the former is the more difficult of construction, and, broadly speaking, the limitations imposed on our production of aircraft will be more likely to come from the side of the engine rather than from that of the plane. An airplane has been aptly termed an engine with wings, and, while much depends on the design and construction of the wings, yet broadly it remains a fact that the number of effective aircraft which we can maintain over the fighting lines will depend primarily on the number of engines which can be built and maintained in effective reliable operation.

In reaching a decision on this point many factors required most careful consideration. The best engines developed in Europe under the stress and urge of war conditions should obviously be better adapted to war airplanes than those developed in the United States during the same period. Such superiority must be accepted as a necessary and natural result of the factors determining the situation. Freely granting this, however, it must be likewise admitted that these engines are for the most part not well adapted to standardization and for rapid production in large numbers. Thus, for example, the builders of one of the very best of the English designs were able to secure a production of only about two hundred engines per year, and the statement was freely made that to produce this engine in the United States it would be practically necessary to bring over the organization of this factory complete and set it down in the States. While this example is perhaps extreme, it is nevertheless true that European designs are generally not well adapted to standardization to the extent necessary if we are to realize the enormous production contemplated. It becomes, therefore, a matter of choice. Either the design must be such as to admit of standardization and construction scattered abroad through and among many shops, or else we must accept a serious sacrifice in the quantity of production.

Large Italian Caproni biplane.

Confronted with a choice among these conditions, the obvious course seems to be to realize, so far as may be, a design paralleling the best European practice and at the same time adapted for standardized methods of production. The components thus sought to be combined in the design should, therefore, be these:

1. The best European design and technical practice.
2. The best of American design and technical practice.
3. Standardization for economic and rapid quantity production.

The story of how the design of the so-called "All America" or "Liberty" engine has developed in accordance with these purposes cannot be told here in more than bold outline.

It is not too much to say that the design and production of the first examples of this engine were little less than an industrial miracle.

In the early days of June two of the leading designers of internal-combustion engines in the country, strangers personally, though well known to each other by reputation and achievement, were called by telegraph to Washington, placed together in a room in the Willard Hotel, and told to design the "All America" engine. With reasonably full information at that time available regarding the design of the leading European types of engine, with the best practice of this country a part of their commonplace knowledge, and with a keen appreciation of the stupendous task of production opening above the horizon, these two designers approached their task. Other engineers and designers of note were called in conference as occasion required. As fast as features and details were determined, they were rushed to draughtsmen installed in a building available at the Bureau of Standards. This work was further supplemented in draughting-rooms scattered over the middle West until some two hundred or more draughtsmen were working in shifts on the detailed structural drawings. These again, as rapidly as completed, were rushed to the manufacturing plants best able to turn out the structural elements, and thus in an incredibly short time the elements of this engine were under construction in some twelve different establishments from the Pacific Coast through the middle West and East, and four weeks from the day when the two designers sat down in their room in the Willard Hotel the first engine was assembled in Detroit, placed on an express car with two special messengers, and rushed to Washington, where it arrived on July 3.

It must further be noted that this piece of design work gave really four engines instead of one. The essentials of design involved in reality a single cylinder and its corresponding moving parts. With these determined, it was a relatively simple matter to provide for combinations into units of four, six, eight, and twelve cylinders each, giving four engines of from 120- to about 350-horsepower capacity. The first shop order comprised five engines of the eight-cylinder and five of the twelve or twin six type, and it was the first of the eight-cylinder type to reach Washington thirty days after the inception of the design as noted above.

The next stage in the program was a series of tests carried out on these first engines and intended to prove out the design in every respect before passing it for quantity production. It would be too much to expect that such a design could be perfect and definitive in every respect. In fact, certain matters of proportion and dimensions could be determined only as the result of test or experience. We must further remember that an aeronautic engine is to really do its work at elevations of 12,000 to 15,000 or 18,000 feet above sea level, while ordinary testing facilities, such as those at most shops and laboratories, are at elevations, for the most part, of only a few hundred feet above sea level. The conditions which prevail at Washington or Detroit or Chicago or at the new aeronautic laboratory at Langley Field, near Hampton, Va., furnish, therefore, no suitable environment within which to determine just how such an engine will perform at an altitude of 15,000 feet. Confronted with this situation, we must either go where suitable conditions do prevail or else provide for them artificially. Actually both courses were taken.

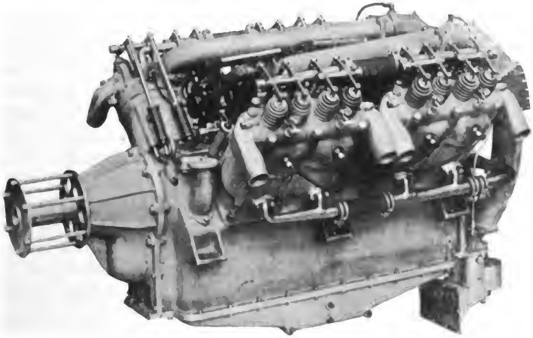
A motor truck was fitted up as a portable testing laboratory with suitable dynamometers and other measuring equipment, the engine was mounted thereon, and the whole combination was shipped to Colorado, where the motor truck was run up the grade of Pike's Peak and the engine tested out at two or three different altitudes.

In the meantime a test chamber for artificially producing conditions similar to those met with at various altitudes was under construction at the Bureau of Standards in Washington and with special reference to a series of tests and investigations on aircraft engines under conditions similar to those which would be met with in free flight at various heights above sea level.

By means of this special equipment, an aeronautic engine may be placed under conditions substantially the equivalent of those met with at any stated altitude, and including any specified air-pressure, temperature, and humidity. This will give sets of controlled conditions under which an engine may be operated at any power and for as long a period as may be desired. The rate of change from one condition to another is also under control, so that the conditions met with in an aeroplane in leaving the ground and mounting to an altitude of, say, 18,000 feet in thirty minutes may be closely paralleled.

This experimental equipment, it is expected, will play an important part in the final development of the Liberty engine and its various special features, such as radiator proportion, carburetor adjustment, muffling, etc.

Regarding the selection of types and characteristics of planes, some reserve must be maintained. As previously noted, the training type has been selected and has been adapted as standard by the British, the Canadian, and the United States governments.



Modern aeronautic engine, 8-cylinder type.

Regarding the design characteristics of the other types, it must perhaps serve to say that the best results of English, French, and Italian practice have been carefully studied and freely used in the selection of type forms and design characteristics for machines of the strictly military class.

But for a great air fleet something more is required than airplanes and engines. Airplanes do not fly and manœuvre themselves, especially not in the manner characteristic of modern air tactics. The human mind and purpose, the brave heart, dauntless courage—these latter are needed to give to the airplane its full significance as a factor in modern warfare. This means the human element, the aviator.

What, then, is the military aviator? A product of what school of training? In what way are we now working to develop this all-essential factor in the air fleet?

The human aviator, developed to the highest degree, is in effect a human bird, a man so developed in his muscular and nervous organization that the airplane has, in effect, become a part of himself—a man whose reactions in the air are as automatic as are those of a bird. But few, however, reach this far-away ideal, and between such goal and the unskilled efforts of the beginner there are indefinite grades of skill, shading one into another and marking the path of progress between the awkward efforts of the beginner and the finished grace and skill of the bird-man. Here, moreover, as in all other branches of human endeavor, there is reserved for a selected few the possibility of the achievement of almost incredible skill—the real ideal of the bird-man. Such are few in number, relatively, and short of these rare prodigies of grace and skill there is fortunately a degree of skill quite sufficient for most military operations and to which larger numbers can attain with average endowments as a foundation and with reasonable perseverance in their development.

The steps actually taken by the United States Signal Corps for the development of aviators for the army are briefly as follows:

Eight educational institutions were first selected for the development of schools of preliminary training for aviation recruits. These institutions, distributed over the United States, are as follows:

The Massachusetts Institute of Technology,
Cornell University,
Princeton University,
The Ohio State University,
The Universiy of Illinois,
The Georgia Polytechnic,
The University of Texas, and
The University of California.

These schools, when equipped and in full running order, are intended to have a capacity of two hundred students (or cadets, as they are called), divided into eight groups or classes. The course is eight weeks in length, and twenty-five cadets are entered at the beginning and twenty-five graduated at the end of the course each week. This secures a steady stream of young men moving along through the eight classes, one class per week, and would thus secure an output of twenty-five students per week for each of the eight schools, or two hundred per week were there no wastage by the way. This would secure a maximum number of graduates of this preliminary training of about 10,000 per year. The capacity of these schools may be greatly increased if necessary, and other schools may be added as occasion may require.

This preliminary training does not include work in the air. It includes, however, certain very necessary courses of instruction intended to give the young aviator some familiarity with the following subjects: military science, practical and theoretical; signalling and radio work; gunnery nomenclature, machine guns, gun sights, fighting tactics, bombs and bomb dropping; theory of flight, cross-country flying, map reading, meteorology, night flying, instruments and observations; types of airplanes, nomenclature, rigging, care, repair; types of internal-combustion engines, laboratory training, care of engines and appliances, troubles and their detection and treatment; airplane tactics, reconnaissance work, artillery spotting, and photography.

With satisfactory progress in these subjects the graduate of the preliminary training is hurried on to actual work in the air at the various flying fields which have been, and are still being, developed in various parts of the United States.

There are some eighteen flying fields now organized in the United States, and more are in contemplation. The number of planes at these fields may vary from twenty or thirty up to one hundred or more.

It will be understood that a field with any given number, such as thirty-six machines, can have under training at any one time several times thirty-six aviators.

In addition to these fields in the United States, use is also made of the British training field at Borden, near Toronto, and certain graduates from the preliminary training are sent direct to undergo their entire training in the air at the fields in France.

It must not be supposed, however, that all the air training is acquired at one place or following a single so-called course. As a matter of fact, the whole curriculum is quite extended and includes at least four divisions or grades, as follows:

1. Elementary training intended to teach a man simply to fly;

to give him confidence in the air and skill in controlling the slower or training machines under ordinary aerial conditions.

2. Training on military machines, including the development of the skill needed for handling the swifter types of planes, practice in machine gun target practice, bomb-dropping practice, radio work, reconnaissance work, artillery spotting, photography.

3. Special or advanced training on military machines, especially of the fighting air-scout types, including trick flying, special tactics, or other special training, according to the adaptation of the student.

4. Final training and practice behind the lines in France and, as nearly as may be, in the atmosphere of the front.

INSTRUMENTAL AND MILITARY EQUIPMENT.

The man and the machine do not quite fill the measure of the requirement for an effective military aircraft. There must be added a series of instruments and items of military equipment which can here be only briefly and somewhat imperfectly noticed.

This secondary equipment divides itself into two main groups —navigating instruments and military equipment.

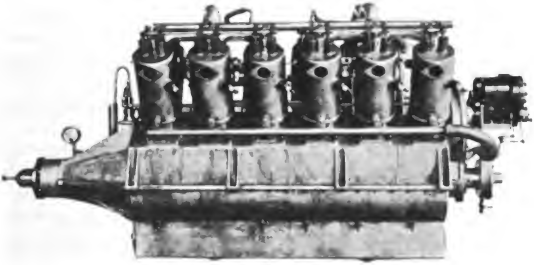
Comprising the former, the following may be mentioned:

1. Altimeter.
2. Airspeed meter.
3. Angle of incidence indicator.
4. Revolution counter and tachometer.
5. Watch.
6. Thermometer.
7. Vertical direction indicator.
8. Drift meter.
9. Compass.
10. Gasoline supply indicator.

No one machine is likely to carry all of these instruments. In fact, in many cases the altimeter, compass, watch, and revolution indicator are considered quite sufficient.

Referring to these instruments briefly, the altimeter is an instrument for measuring or indicating the altitude of the airplane above the earth's surface. It consists usually of some form of aneroid barometer adapted to this special purpose and graduated so as to read altitude above the sea level in either feet or metres, as desired.

The airspeed meter is an instrument for indicating the speed of the airplane through or relative to the air in which it is moving. Several forms have been devised, those most commonly used depending upon either the Pitot tube or the Venturi tube principle. In no case will the airspeed meter give any reliable indication of the speed over the ground. This will depend on the speed through the air and on the wind velocity or the speed of air movement relative to the ground. Thus with an airplane flying into a head wind with a velocity of thirty miles per hour the speed through the air may be ninety miles per hour, while the speed over the ground will be only sixty miles per hour, while if flying with the same wind the speed over the ground will be one hundred and twenty miles per hour. The indications of the airspeed meter have, therefore, small value for purposes of navigation, properly speaking, but they do have some relation to the proper speed of the plane with reference to its load and climbing angle.



Modern aeronautic engine, 12-cylinder type.

The angle of incidence meter is intended to show the angle between the chord of the main planes and the direction of its movement. This indication also has chief relation to the safe and proper condition of the plane with reference to its load and climbing angle.

The revolution counter and tachometer is intended to give an instantaneous indication of the rotative speed of the propeller shaft and a continuous total of the same over any trip or period of time. Though usually different in form, it serves the same purpose as the corresponding and familiar instrument found on every automobile. Since, moreover, the slip of the propeller is fairly uniform under uniform conditions, the instantaneous indications of the shaft may be made to give an indication of the speed through the air which may be checked against the indication of the air speed meter.

The significance of the watch is obvious, and it is commonly worn on the wrist, also for obvious reasons.

The thermometer is of significance only for meteorological observations and may or may not be included in the equipment, according to the purposes in view.

The vertical direction indicator is often of significance when flying in the night or in a fog or cloud. Especially in the latter case, if the machine is circling, it becomes very difficult to determine by the ordinary sense of balance or orientation the direction of the true vertical. The principles of the gyroscope are found most available for realizing an instrument which may be made to give at all times an indication of the true vertical.

The drift meter is an instrument intended to give the angle between the actual path of forward motion and the fore-and-aft line of the machine. It is clear that if an airplane is flying side to the direction of the wind, then, relative to the earth, the machine will sidle off obliquely along a path the direction of which will lie between that of the propeller shaft and that of the wind. The actual direction of travel relative to the earth is of importance in many military operations, especially in bomb dropping, and some means for obtaining an indication or measure of this angle is therefore necessary for such operations. One form of drift meter which illustrates the principle usually employed comprises a form of telescope pointing vertically downward and with a grating of parallel spider-web filaments. Looking through this telescope on the ground below, the lines of flow backward of objects on the ground may be observed, and the telescope may be revolved about its axis until such lines are parallel to or along the grating filaments. The angle made between those filaments and the fore-and-aft direction is then read on a suitable scale, thus giving the angle of drift.

The use of the compass is too obvious to need special note. The form commonly employed is a special construction of the so-called marine or card form adapted to aircraft service.

The special military armament of airplanes comprises the machine gun, the bomb, and the radio equipment. The machine gun and the bomb have been already noted in connection with the fighting and the bombing types of airplanes.

Regarding the radio equipment, reference has been already made to the function of the reconnaissance and spotting plane—the prompt report of information back to the higher command. To this end, wireless telegraphy has been developed to the point where it has played a most important rôle. The modern reconnaissance or spotting airplane is therefore fitted, at least, with a sending radio outfit capable of sending messages to points several miles distant and of thus communicating instantly the results of their visual observations. This outfit requires a source of electric energy, and this requires a suitable generator and a source of power. The latter is often found in the movement of the plane, the usual type of generator comprising a form of air-wheel or propeller actuated by the movement through the air and thus driving an electric generator suited to the requirements of the radio equipment.

The full development of wireless telegraphy, however, implies receiving as well as sending. This, with the noise inseparable from the operation of the airplane, presents many very difficult problems. The results realized here can only be referred to with reserve, but it may be said that gratifying progress has been made in the solution of such problems, and within certain ranges messages may be received as well as sent.

This permits of the aviator keeping fully in touch with his base when in the air, and also lays a foundation for squadron airplane tactics and evolution, not readily practicable without some means of transmitting and receiving commands from one plane to another.

But the plans for a great air fleet are not limited to use by the army and on the fighting lines in France or elsewhere. There is also the work of the navy, with its squadrons of seaplanes for coast patrol and its scouting seaplanes for service against the submarine.

Plans have been formulated for a number of coast patrol centres along the Atlantic, as well as on the Pacific and in the insular possessions of the United States, all for our own defence. In addition, the United States is counting on furnishing for the coastal waters of France and England a still larger number of squadrons of seaplanes for scouting and patrol, with special reference to submarine detection and offence.

Specific numbers cannot, of course, be mentioned, but the aggregate of the seaplane squadrons, either provided for or in contemplation, will represent a very significant addition to the coast patrol forces of the European Atlantic waters and a good beginning on an adequate patrol service for our own coasts.

For the training of pilots for these seaplanes there have been also established, at a series of points on the sea-coasts of the United States, training schools where a large number of men have been and are continuously under instruction and training for this branch of the service. The general character of the training is similar to that employed for the development of the pilot of the land machine and need not be here considered in detail.

For coast patrol work, seaplanes are used either of the pontoon or flying-boat type and one-place or two-place in carrying capacity. They are provided with machine-gun offensive armament, and may carry a further weight in bombs, according to size and character of service.

The general problems arising in the navigation of seaplanes, their equipment with military armament, etc., are entirely similar to those for airplanes used for service over the land, and do not, therefore, call for further special notice.

Perhaps the most distinguished general characteristic of the development of an airplane service is the rapidity of change in types of machines and in standards of performance. The three years' progress of war on the western front in France has seen the rise and eclipse of dozens of types of machines of various technical characteristics and qualities. There are now in use along this front perhaps some two dozen types of machines, but how soon others of improved characteristics may appear and relegate most of them to the rear or for secondary service, the future of to-morrow or next week or next month or next spring alone can tell. Herein enters one of the difficulties of standardization. Unity of design and standardized construction through templates and gauges are a necessity for the most rapid industrial production, but no such condition can be allowed to stand in the way of improvement in design and technical quality, and so we must adjust ourselves to some compromise which will secure the maximum industrial production compatible with a quick response to the changing conditions developed by the military demands of the situation and to the advance of the art through research, invention, and experience.

The great war has now reached a stage when in a very real sense the eyes of the world are upon us, and our allies echo the thought that the way to victory lies through the air, and they are now awaiting the moment when we shall be able to lend our effort in such degree as shall furnish a really determining factor.

In no way can we do this so effectively or so quickly as through the air. If we stand true to our traditions of 1776, of 1812, of 1861, of 1898, we shall not fail to measure up to the needs of the situation, and we shall, with our pilots in the air, our boys in the trenches, and our sailor lads on the deep, finally be able to justify the reasonable expectations of our allies as the last great source of power in the struggle for the overthrow of the great arch-enemy of government of, by, and for the people.

Increase in Production of Natural Gas. ANON. (*U. S. Geological Survey Press Bulletin*, No. 341, November, 1917.)—Statistics just compiled under the supervision of J. D. Northrop, of the United States Geological Survey, Department of the Interior, show that the volume of natural gas commercially utilized in the United States in 1916 was greater than that so utilized in any other year in the history of the natural-gas industry. The volume used, which amounted to 753,170,253,000 cubic feet, constitutes a new record, exceeding by nearly 125,000,000,000 cubic feet, or 20 per cent., the former record, established in 1915. The average price of this gas at the point of consumption was 15.96 cents a thousand cubic feet and its total market value was $120,227,468, a loss of 0.16 cent in unit price, but a grain of $18,915,087, or 18.6 per cent., in total value compared with 1915.

The general increase in the production of natural gas in the United States in 1916 is attributed principally to an enormous expansion of the casing-head gasoline industry in all natural-gas producing states and to a greatly augmented demand for natural gas as fuel by industries engaged in the manufacture of munitions of war. The influence of this demand is shown in the increase in the volume of gas distributed to industrial consumers and in the increase in the value of gas consumed, its effect being sufficient to lower the average price per thousand cubic feet of all gas sold in 1916 1 per cent. as compared with 1915.

Carbon Tetrachloride as a Cleaning and Solvent Agent. ANON. (*Quarterly of the National Fire Protection Association,* vol. xi, No. 2, p. 173, October, 1917.)—Carbon tetrachloride is a water-white liquid having, when pure, a pleasant odor quite similar to that of chloroform. The commercial product usually contains sulphur impurities which impart a somewhat disagreeable odor. The specific gravity of the liquid at 32° F. is 1.632 and the boiling-point is 169° F. The specific gravity of the vapor is about five and a half times as great as that of air and about twice as great as that of the lightest napthas. The difference in specific gravities of the vapors of carbon tetrachloride and naphtha is not sufficiently great, however, to overcome the tendency which all vapors have to diffuse one within the other, and the two vapors do not separate, once they have become thoroughly mixed. The two liquids also show no tendency to separate after mixing.

Carbon tetrachloride is an excellent solvent of animal and vegetable fats, oils, varnishes, waxes, resins, mineral oils, paraffin tar, etc. It is non-inflammable and non-explosive. Combustion cannot take place in its vapor, due to the absence of oxygen. For that reason it extinguishes small fires in enclosed spaces when thrown into them. The toxic properties of carbon tetrachloride are of importance where large quantities are used and no provision is made for removing the vapors. Its effect on the human system is the same as that of chloroform, producing anæsthesia, though not as powerful in its action.

Until recently the cost of manufacture of carbon tetrachloride has been so great as to prohibit its general technical application, although for cleaning purposes, such as degreasing wool and removing oil and grease spots from finished cloth, it is fully as efficient as naphtha. Owing to this property, it is being used in a large number of patented preparations intended for use as cleaning agents, and is being sold under a variety of special trade names. These preparations sometimes contain other substances besides carbon tetrachloride, but they generally possess little or no advantage over the latter.

On account of its non-inflammability and property of smothering small fires, carbon tetrachloride is being sold to-day as a fire-extinguishing agent. In this rôle it has, however, the disadvantage of liberating large quantities of suffocating and poisonous gases, and it is necessary to confine the vapor to the immediate seat of the fire. Its high cost, despite further recent reductions in price, is still the one serious drawback to its more general application, but the many advantages which carbon tetrachloride possesses over naphtha in point fo safety make its use very desirable wherever practicable. The cost can be considerably reduced in many instances by reclaiming the spent solvent by distillation and by taking advantage of the fact that a certain percentage of naphtha can be added without making the mixture inflammable.

OUTLINE OF COLLOID CHEMISTRY. I.*

BY

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ADSORPTION OF GASES, LIQUIDS AND SOLIDS.

INTRODUCTION.

IN 1861 Graham[1] pointed out that substances like potassium hydroxide, potassium sulphate, magnesium sulphate, sugar, and alcohol diffuse much more rapidly in aqueous solution than hydrated silicic acid, hydrated alumina, starch, dextrin, the gums, tannin, albumin, gelatin, etc. Since these latter substances are apt to occur in a gelatinous or non-crystalline form, Graham suggested calling them "colloids," from the French word for glue. Substances which diffused readily were to be called "crystalloids," because most of them crystallize readily. Graham believed that the distinction between a crystalloid and a colloid was due to some molecular condition. Though modern colloid chemistry begins with Graham,[2] his distinction between crystalloids and colloids has been dropped. We now speak of a colloidal state instead of a colloidal substance, and we call any phase colloidal when it is sufficiently subdivided,[3] the particular degree of subdivision being quite arbitrary.

According to this definition, colloid chemistry is the chemistry of bubbles, drops, grains, filaments, and films. At first sight this might not seem an important branch of chemistry, either theoretically or technically; but this opinion changes when we consider that a knowledge of colloid chemistry is essential to anybody who wishes to understand about: cement, bricks, pottery, porcelain, glass, enamels; oils, greases, soaps, candles; glue, starch, and adhesives; paints, varnishes, lacquers; rubber, celluloid, and other plastics; leather, paper, textiles; filaments, casts, pencils and crayons; inks; roads, foundry cores, coke, asphalt; graphites, patines, zinc, phosphorus, sodium, and aluminum; contact sulphuric acid, hardened oils, etc.; beer, ale, and wine; cream, butter, cheese, and caseine products; cooking, washing, dyeing, printing; ore flotation, water purification; sewage disposal; smoke prevention; photography; wireless telegraphy; pharmacy; physiology. In other words, colloid chemistry is the chemistry of daily life.

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* Based on a paper presented at the meeting of the Section of Physics and Chemistry held Thursday, January 11, 1917.

[1] *Phil. Trans.* **151**, 183 (1861); *Jour. Chem. Soc.* **15**, 216 (1862); **17**, 318 (1864).

[2] Interesting work was done by Selmi in 1844, but it had no appreciable effect on the development of scientific thought.

[3] Cf. Wolfgang Ostwald, "Grundriss der Kolloidchemie," 79 (1909).

ADSORPTION OF GASES AND VAPORS BY SOLIDS.

In an extremely subdivided phase the surface is very large relatively to the mass of the phase, and therefore the first step in the study of colloid chemistry is to discuss the properties of surfaces, beginning with the behavior of solids in contact with gases or vapors. All solids tend to adsorb, or condense upon their surfaces, any gases or vapors with which they are in contact. The amount of adsorption varies with the nature and physical state of the solid and with the nature of the gas; in other words, the adsorption is specific or selective. The amount of gas adsorbed is greater the higher the pressure and the lower the temperature. In Table I are given some data to illustrate these points. Hempel and Vater[4] used a particular commercial animal charcoal which they mixed to a stiff paste with ox-blood diluted tenfold with water and which they then charred at 600°. In Table II are some data by Dewar[5] with cocoanut charcoal. The volumes of gas adsorbed have been calculated back to standard conditions; in other words, to the volumes which the adsorbed gases would occupy at 0° and 760 mm. pressure. Thus at −185° and 760 mm.

TABLE I.

Cubic Centimeters of Gas adsorbed by 1 c.c. Synthetic 600° Charcoal; Volumes probably corrected to 0° and 760° mm.

	+20°	—78°	—185°		+20°
H_2	7.3	19.5	284.7	NH_3	197.0
N_2	21.0	107.4	632.2	H_2S	213.0
CO	26.8	139.4	697.0	Cl_2	304.5
O_2	25.4	122.4	....	SO_2	337.8
	+20°	—78°		+20°	—78°
CO_2	83.8	568.4	CH_4	41.7	174.3
NO	103.6	231.3	C_2H_6	119.1	275.5
N_2O	109.4	330.1	C_2H_4	139.2	360.7
Ar	12.6	92.6	C_2H_2	135.8	488.5

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[4] *Zeit. Elektrochemie*, **18**, 724 (1912).

[5] *Proc. Roy. Soc.*, **74**, 124 (1904).

TABLE II.

Cubic Centimeters of Gas adsorbed by 1 c.c. Cocoanut Charcoal; Volumes corrected to 0° and 760 mm.

	0°	—185°		0°	—185°
He	2	15	CO	21	190
H_2	4	135	Ar	12	175
N_2	15	155	O_2	18	230

the actual volumes of gas adsorbed would be only 88/273, or approximately one-third of the values given in Table II. The difference between the two charcoals is noticeable at the higher temperatures and becomes very marked at −185°. Data for many other gases and vapors are to be found in papers by Hunter.[6]

As a first approximation, it is often stated that a gas or vapor is adsorbed more readily, the higher its boiling-point. Thus helium is taken up by charcoal much less than hydrogen, and hydrogen again is adsorbed to a less extent than nitrogen or oxygen. Carbon dioxide is adsorbed more readily than oxygen and less readily than ammonia, so that these six substances follow the empirical rule. Argon, however, is adsorbed less readily by charcoal than either oxygen or nitrogen, while carbon monoxide is adsorbed to a greater extent at 0° than either argon or oxygen, though this ought not to be so. Nitrous oxide is adsorbed less readily than ethylene and acetylene, which is not according to the boiling-points. Nearly three times as much hydrogen sulphide as carbon dioxide is adsorbed at +20°, though the boiling-point of the first, −73°, differs but little from the sublimation point of the second, −79°. Hydrogen sulphide is adsorbed more than ammonia, which is wrong, and chlorine is adsorbed much more strongly than ammonia, although the two boiling-points are practically identical. Cyanogen is adsorbed more than ammonia at 70° and less at 0°. In the case of vapors there is no relation between boiling-point and adsorption. Going from higher to lower boiling-points, we have the order: water, benzene, ethyl alcohol, carbon tetrachloride, methyl alcohol, chloroform, ether, and aldehyde. The order from greater to lesser adsorption is: aldehyde, methyl alcohol, ethyl alcohol, ether, benzene, water, chloroform, and carbon tetrachloride. The truth of the matter is that adsorption is specific and varies with the nature of the gas and of the adsorbing solid. It is fairly obvious what characteristics a charcoal should have in order to adsorb well; but this is unfortunately a military question and therefore cannot be discussed now.

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[6] *Phil. Mag.* (4), **25**, 364 (1863); *Jour. Chem. Soc.*, **18**, 285 (1865); **20**, 160 (1867); **21**, 186 (1868); **23**, 73 (1870); **24**, 76 (1871); **25**, 649 (1872).

The adsorption of gases by charcoal has been made use of by Tait and Dewar[7] as a means of getting a high vacuum. A bulb of air, 300 c.c. capacity, containing air at 15° and an initial pressure of 1.7 mm., was connected to a charcoal condenser containing five grammes of charcoal.[8] When the charcoal was cooled in liquid air, the pressure dropped to 0.000047 mm. Some of the digestive tablets taken by people after their meals consist largely of charcoal, and one of their functions is to adsorb gases in the stomach which would otherwise give rise to discomfort.

Since different gases are adsorbed in different amounts, the ratio of two gases in the charcoal will differ from the ratio in the gas phase and a fractional separation will be possible to some extent. Dewar[9] passed air at −185° over charcoal and obtained 98 per cent. nitrogen, while the adsorbed gas contained 55 per cent. oxygen. Above +100° the adsorbed oxygen reacts when the charcoal is heated and comes off as carbon monoxide and carbon dioxide. The data in regard to this are very unsatisfactory.[10] The general rule for mixtures of gases seems to be[11] that the more readily adsorbed gas displaces the other to some extent and is therefore adsorbed more relatively than one would have expected from experiments on the single gases. This is not universally true. Bergter[12] found that at pressures of 0.5 to 10 mm. oxygen is adsorbed 30 to 40 times as strongly as nitrogen, and that at these pressures the presence of oxygen increases the amount of nitrogen adsorbed. With readily condensible gases, it is not unusual to have one of the vapors increase the adsorption of the other.[13] A striking instance is with water and ammonia. It seems probable that the adsorbed water dissolves or adsorbs ammonia, thus increasing the amount of ammonia apparently held by the charcoal.

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[7] *Proc. Roy. Soc. Edin.*, **8**, 348, 628 (1874).

[8] Dewar, *Proc. Roy. Inst.*, **18**, 437, 756 (1906).

[9] *Proc. Roy. Soc.*, **74**, 126 (1904); *Proc. Roy. Inst.*, **18**, 184 (1906).

[10] Blumtritt, *Jour. prakt. Chem.*, **98**, 418 (1866); Baker, *Jour. Chem. Soc.*, **51**, 249 (1887); Rhead and Wheeler, *Ibid.*, **103**, 461, 1210 (1913); Manville, *Jour. Chim. phys.*, **5**, 297 (1907).

[11] Freundlich, "Kapillarchemie," 99 (1909).

[12] *Drude's Ann.*, **37**, 480 (1912).

[13] Hunter, *Jour. Chem. Soc.*, **23**, 73 (1870).

The adsorption of gases by charcoal has been studied extensively, because charcoal adsorbs so many gases and adsorbs them so strongly. Experiments have also been made with all sorts of other adsorbing agents—silica, alumina, glass, wool, rubber, celluloid, meerschaum, metals, soils, etc. The behavior of glass is important because of its use in the laboratory. Mülfarth[14] found that the adsorption decreased in the order: NH_3,SO_2,CO_2, N_2O,C_2H_2. Kundt and Warburg[15] found that a small amount of water is retained obstinately by glass even when the pressure is reduced practically to zero. In order to remove this water the glass must be heated. On the other hand, the film of water which usually covers the glass surfaces is due chiefly to alkali dissolved from the glass.[16] L. J. Briggs[17] showed that finely divided quartz adsorbs water vapor, though not to the same extent as amorphous silica. About 9 mg. water was adsorbed at 30° by 50 g. quartz having an estimated surface of 20,000 cm.^{2} when the vapor pressure was 26.1 mm., about 4.5 mg. when the vapor pressure was 19.6 mm. and about 0.5 mg. when the vapor pressure was 0.2 mm. Cohnstaedt[18] believes that the gas given off by aluminum electrodes in a Crookes tube is water vapor, and not hydrogen, as usually believed. He claims to prove that glass and aluminum surfaces will retain water even when heated to 500° or when dried over phosphorus pentoxide.

It is the presence of a water film of varying thickness on a glass or other vessel which makes it necessary to keep the moisture constant if accurate weighings are to be made. Professor Morley once said that it was a mistake to believe that it is a difficult matter to dry a gas. That is a very simple thing to do. The difficulty is to dry the vessel which holds the gas.

Drucker and Ullmann[19] showed that the adsorption of a vapor by the glass containing-vessel causes only a negligible error in vapor-density determinations with ether, alcohol, benzene, and chloroform; but the error may amount to two per cent. with acetic acid at 80°. At higher temperatures the adsorption decreases and the error is correspondingly less. The adsorption of ammonia by solid ammonium hydrosulphide introduces a serious error in the equilibrium relations of ammonia and hydrogen sulphide.[20]

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[14] *Drude's Ann.*, **3**, 328 (1900).

[15] Cf. Bunsen, *Pogg. Ann.*, **156**, 201 (1875); *Wied. Ann.*, **24**, 327 (1884).

[16] Warburg and Ihmori, *Wied. Ann.*, **27**, 481 (1886); Ihmori, *Ibid.*, **31**, 1006 (1887).

[17] *Jour. Phys. Chem.*, **9**, 617 (1905).

[18] *Drude's Ann.*, **38**, 223 (1912).

[19] *Zeit. phys. Chem.*, **74**, 567 (1910).

Platinum black may take up 100 volumes of hydrogen and palladium nearly up to 3000 volumes of hydrogen,[21] but it is not certain whether this hydrogen is all adsorbed or is partly dissolved. In gas analysis, palladium, heated at 100°, is used to remove hydrogen. This is purely a question of rate. Equilibrium is reached more rapidly at the higher temperature, though the palladium cannot take up so much hydrogen as at lower temperatures. Platinum black will take up more than 800 volumes of oxygen; but it seems certain that in this case some of the platinum has been oxidized.[22] Celluloid adsorbs carbon dioxide, and rubber apparently adsorbs it [24] as well as other gases, though it is possible that we have true solution in the case of rubber. Wool [25] adsorbs either hydrochloric acid gas or ammonia gas. Ramsay [26] considers that the nitrogen found in zinc is due to ammonia adsorbed from the air by the zinc.

If the film of adsorbed air on a small particle remains approximately of the same thickness, irrespective of the diameter of the particle, the ratio of air film to mass of particle will increase as the particle grows smaller. Cushman and Coggeshall [27] found that a rock powder which would pass through a 200-mesh sieve surged like a liquid. When poured into a vessel, it filled only 46 per cent. of the space, while coarser powder filled more. It is not surprising that the air-cushion round each particle makes the grains move over one another like a liquid. With a substance like carbon black, which adsorbs gases very markedly, as little as 5 per cent. of the apparent volume may be due to the carbon black,[28] and a liter of carbon black may contain 2.5 liters of air.[29]

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[20] Magnusson, *Jour. Phys. Chem.*, **11**, 21 (1907).

[21] Paal and Gerum, *Ber. deutsch. chem. Ges.*, **41**, 805 (1908).

[22] Engler and Wöhler, *Zeit. anorg. Chem.*, **29**, 1 (1901).

[23] Lefebvre, *Jour. Chem. Soc.*, **105**, 328 (1914).

[24] Reychler, Van Bemmelen Gedenkboek, 55 (1910).

[25] Freundlich, "Kapillarchemie," 106 (1909).

[26] *Chem. News*, **92**, 80 (1905).

[27] *Jour. Franklin Inst.*, **174**, 672 (1912).

[28] Cabot, *Eighth Int. Congress Applied Chem.*, **12**, 18 (1912).

[29] Sabin, "Technology of Paint and Varnish," 201 (1917).

When indigo is reduced to a very fine powder [30] the single particles appear to be separated from one another by an envelope of air, so that the dry, solid powder occupies a space equal to that of a 20 per cent. paste of indigo containing the same amount of indigo. The presence of a film of air or vapor round a solid particle is shown in a striking way by the fact that it is quite a simple matter [31] to pass suspended phosphorus pentoxide through several wash-bottles in spite of its tremendously hygroscopic nature. Since the sulphur trioxide from the contact process can be caught in concentrated acid but not satisfactorily in water, we know that the concentrated acid displaces the gas film rapidly and fairly completely, while water does not; but we do not yet know what the reason for this is.

From experiments on the disruptive discharge through gases, Schuster [32] concluded that there was a condensed surface layer of gas having a high inductive capacity in contact with the solid electrode. Since this layer of adsorbed gas offers an increased resistance to the electrical discharge, it follows, from the theorem of Le Chatelier, that an electrical stress will tend to remove the film of adsorbed gas. This enables us to account for many apparently unrelated facts. Electrical waves tend to remove active oxygen and active hydrogen from an electrode and will therefore cut down the over-voltage.[33] Superposing an alternating current on a direct current also decreases the over-voltage,[34] making other reactions possible. The experiments of Margules [35] and of Ruer [36] on the dissolving of platinum find their explanation in the cutting down of the over-voltage.[37] With direct current there is oxidation to a higher and insoluble stage. With alternating current the over-voltage is decreased and little or none of the insoluble compound is formed. The electrolytic detector, the crystal detector, and the coherer, as used in wireless telegraphy,[38] owe their action to the partial or complete elimination of an air film by means of an electrical stress. In connection with this it is interesting to note that Lenard[39] found that mercury wets platinum only when a current is flowing. At other times there is evidently an air film. It has been claimed by Allen[40] that the photo-electric fatigue of metals is due to a change in the surface film of gas or in the gas occluded in the metal (Hallwachs). It cannot be due to a chemical change such as oxidation; to a physical change such as roughening of the surface; to an electrical charge in the formation of an electrical double layer (Lenard); or to a disintegration of the metal due to the expulsion of electrons by light (Ramsay and Spencer). The difference in the results obtained by Allen and by Robinson[41] may be due to the fact that Allen worked at atmospheric pressure, while Robinson's measurements were made on electrodes in a high vacuum.

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[30] Willcox, *Jour. Soc. Dyers and Colourists*, **17**, 294 (1901).

[31] Engler and Wild, *Ber. deutsch. chem. Ges.*, **29**, 1929 (1896).

[32] *Phil. Mag.* (5), **29**, 197 (1890).

[33] Bennewitz, *Zeit. phys. Chem.*, **72**, 223 (1910); Rothmund, *Drude's Ann.*, **15**, 193 (1904).

[34] Archibald and von Wartenberg, *Zeit. Elektrochemie*, **17**, 812 (1911); Reitlinger, *Ibid.*, **20**, 261 (1914); Ghosh, *Jour. Am. Chem. Soc.*, **37**, 733 (1915); Stepanov, *Chem. Abstracts*, **10**, 2431 (1916).

[35] *Wied. Ann.*, **65**, 629; **66**, 540 (1898).

[36] *Zeit. phys. Chem.*, **44**, 81; *Zeit. Elektrochemie*, **9**, 235 (1903); **11**, 10, 661 (1905); Haber, *Zeit. anorg. Chem.*, **51**, 365 (1906).

[37] Zeitlinger, *Zeit. Elektrochemie*, **20**, 261 (1914).

In cases of marked adsorption of gases it is interesting to determine what is the probable density of the adsorbed gas. Mitscherlich[42] calculated that when carbon dioxide at atmospheric pressure and 12° is adsorbed by boxwood charcoal the carbon dioxide occupies only one fifty-sixth of its original volume. Since this is a lesser volume than the same amount of carbon dioxide can occupy as gas at this temperature, it follows that some of it had been liquefied. Dewar[43] has calculated the apparent density of some gases adsorbed by cocoanut charcoal at low temperatures. The densities of the adsorbed gases are of the same order as those of the liquefied gases, and are greater in some cases. At higher temperatures the amount of adsorption would be smaller and the apparent condensation less.

It is to be noticed that the vapor pressure of a film of adsorbed gas in an apparently liquefied state stands in no relation to the vapor pressure of a mass of the liquefied gas. The phase rule generalization that the vapor pressure is constant for the system, liquid and vapor at constant temperature, holds good explicitly only in case the disturbing effects due to gravity, electricity, distortion of the solid masses, and capillary tensions are eliminated. So soon as a liquid film becomes thin enough so that the liquid no longer has the property of matter in mass, the vapor pressure need not remain constant. When we have an adsorbed liquid or liquefied gas the vapor pressure will vary also with the nature of the adsorbing agent. The lowering of the vapor pressure is shown by the fact that oatmeal,[44] previously dried at a high temperature, has been used instead of sulphuric acid to produce the freezing of water under the receiver of an air-pump.

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[38] Bancroft, *Jour. Phys. Chem.*, **20**, 503 (1916).

[39] *Wied. Ann.*, **30**, 212 (1887).

[40] *Phil. Mag.* (6), **20**, 564 (1910); cf. Lenard, *Drude's Ann.*, **8**, 196 (1902); **12**, 490 (1903).

[41] *Phil. Mag.* (6), **23**, 255 (1912).

[42] *Sitzungsber. Akad. Wiss. Berlin*, 1841, 376.

[43] *Proc. Roy. Inst.*, **18**, 438 (1906).

Since the amount of adsorption increases very rapidly with falling temperature, there must be a very marked evolution of heat, and this is the case. In Table III are given some data by Favre.[45] The bracketed values are not his. All the heats of adsorption are higher than the corresponding heats of liquefaction. The abnormally high values for hydrogen in palladium and platinum cannot be due to dissociation into monatomic hydrogen, because that would be accompanied by an absorption of heat. They may be due in part to an oxidation of hydrogen. Masson[46] considers that the heat of adsorption of water vapor does not differ materially from the heat of liquefaction; but Dewar's data[47] confirm those of Favre, and we know also that

TABLE III.

Molecular Heats of Adsorption and of Liquefaction of Gases.

Adsorbing agent	Gas	Adsorption Gram calories	Liquefaction Gram calories
Platinum	H_2	46200	
Palladium	H_2	18000	
Charcoal	NH_3	5900 – 8500	[5000]
Charcoal	CO_2	6800 – 7800	6250
Charcoal	N_2O	7100 – 7700	4400
Charcoal	SO_2	10000 – 10900	5600
Charcoal	HCl	9200 – 10200	[3600]
Charcoal	HBr	15200 – 15800	[4000]
Charcoal	HI	21000 – 23000	[4400]

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[44] Thomson, *Phil. Mag.* (4), **42**, 448 (1871).

[45] *Ann. Chim. Phys.* (5), **1**, 209 (1874).

[46] *Proc. Roy. Soc.*, **74**, 249 (1904).

[47] Dewar, *Proc. Roy. Inst.*, **18**, 183 (1905).

there is always a heat effect when porous solids are wetted by liquids.[48] This is probably due to an actual increase in the density of the adsorbed liquid. No one seems to have measured the change of the heat of adsorption with change of temperature.

The effect of traces of impurity on the adsorption is shown in some experiments by Berliner.[49] His purified palladium foil adsorbed about 860 volumes of hydrogen. If allowed to stand in the apparatus in a vacuum for an hour, it then adsorbed practically no hydrogen. If left for an hour or two in the air, the same thing happened. The disturbing factor is apparently a trace of grease, because water did not wet the soiled palladium. Similar results were obtained with platinum.

It is now advisable to consider the quantitative relation between pressures and adsorption.[50] If we plot the amounts of adsorbed gas as abscissæ and the pressures as ordinates, we get the so-called adsorption isotherm, a smooth curve concave to the pressure axis. If the gas is adsorbed strongly, the isotherm bends round at higher pressures to run nearly parallel with the pressure axis, because at these pressures a marked increase in pressure produces a relatively slight increase in adsorption. With gases, which are not adsorbed so readily, this latter portion of the curve is not reached at atmospheric pressure, which is as high as most people go. With ammonia in charcoal one can get the first type by working at 0° or lower, and the second type by working at 150°. If we plot the logarithms of the amounts of adsorbed gas against the logarithms of the pressures, we get a curve which approximates a straight line if the gas is not adsorbed too strongly. This shows that the data can be represented approximately by an equation of the form,

$$(x/m)^n = kp$$

where x is the amount of gas adsorbed and m the amount of adsorbing solid, while p is the pressure, and k and n are constants to be determined experimentally for each temperature.[51] The exponential factor n is so usually not an integer and its physical significance is unknown. In Table IV are some data by Geddes[52]

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[48] Cf. Pouillet, *Ann. Chim. Phys.* (2), **20**, 141 (1822); Chappuis, *Wied. Ann.*, **19**, 21 (1883); Martini, *Phil. Mag.* (5), **47**, 329 (1899); **50**, 618 (1900); (6), **5**, 595 (1903); Parks, *Ibid* (6), **4**, 240 (1902); **5**, 517 (1903).

[49] *Wied. Ann.*, **35**, 803 (1888).

[50] Cf. Travers, *Proc. Roy. Soc.*, **78A**, 9 (1906); Davis, *Jour. Chem. Soc.*, **91**, 1066 (1907); Geddes, *Drude's Ann.*, **29**, 797 (1907); Boyle, *Jour. Phys. Chem.*, **12**, 404 (1908); *Phil. Mag.* (6), **17**, 377 (1909); McBain, *Ibid.*, **18**, 916 (1909); *Zeit. phys. Chem.*, **68**, 471 (1909); Homfray, *Ibid.*, **74**, 139, 687 (1910); Titoff, *Ibid.*, **74**, 641 (1910); Piutti and Maglia, *Gazz. chim. ital.*, **40 i**, 569 (1910).

TABLE IV.

Adsorption of Carbon Dioxide by Charcoal.

Formula $x^{1.77}p = 0.0602$.
x = c.c. CO_2 adsorbed per c.c. charcoal.
p = pressure in mm. Hg. Temperature 31°.

p	x found	x calculated	p	x found	x calculated
41.5	1.7	1.7	453	6.5	6.4
120	2.9	3.1	534	7.1	7.1
194	4.0	4.0	602	7.6	7.6
276	4.7	4.9	678	8.3	8.2
340	5.4	5.5	698	8.6	8.3
405	5.9	6.0	73	8.9	8.4

on the adsorption of CO_2 by charcoal. The formula enables us to calculate the adsorption with a moderate degree of accuracy, but cannot possibly represent the facts for pressures at which the curve runs nearly parallel to the pressure axis.

The fact that we get a smooth curve when plotting pressure direct against adsorption shows that no definite compound is formed. The type of curve is characteristic of a continuous series of solid solutions or of an adsorption. The equilibrium is usually reached fairly rapidly, which is an argument against the existence of a solid solution, though by no means a conclusive one. More convincing is the fact that the amount of adsorption by charcoal varies with the structure.[53] While the experiments on the taking up of gases by charcoal show fairly conclusively that the surface phenomena are the important ones, there is always the possibility that a solid solution may also be formed to some extent. McBain[54] considers that over 13 per cent. of the hydrogen taken up by cocoanut charcoal at the temperature of liquid air is present as a solid solution.[55] On the other hand,

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[51] For a slightly different formulation, see Williams, *Trans. Faraday Soc.*, **10**, 167 (1914).

[52] *Drude's Ann.*, **29**, 797 (1909).

[53] Piutti and Maglia, *Gazz. chim. ital.*, **40 i**, 569 (1910).

[54] *Phil. Mag.* (6), **18**, 916 (1909); *Zeit. phys. Chem.*, **68**, 471 (1909).

[55] Cf. Travers, *Proc. Roy. Soc.*, **78** A, 9 (1906).

Titoff[56] believes that the amount of hydrogen dissolved in the charcoal has been overestimated by McBain.[57] The truth of the matter is that we have no definite criterion which will enable us to distinguish accurately in all cases between solid solution and adsorption. In the case of gelatine and of cellulose it is quite possible that some water is actually dissolved. Until we know more about the subject it is safer to treat any doubtful case as chiefly one of adsorption.

On the other hand, the two special cases of metals and rubber with gases call for some special comment. Assuming the existence of pores in platinum or palladium foil, one can account for the selective diffusion of hydrogen by postulating adsorption in the pores and subsequent diffusion. At high temperatures the adsorption would be much less, and it is difficult to account for the increased rate of selective diffusion. It is simpler to account for the diffusion of hydrogen through platinum by postulating that some of the hydrogen actually dissolves in the platinum. In that case the solubility should be independent of the physical structure of the platinum. This seems to be true within narrow limits for platinum and within wide limits for palladium. It seems probable that platinum can dissolve several volumes of hydrogen at ordinary temperatures, and palladium nearly eight hundred volumes.[58] The bulk of the hundred volumes of hydrogen which are taken up by platinum black[59] must be adsorbed, and the same must be true of the nearly 3000 volumes taken up by colloidal platinum.[60] This is apparently the conclusion reached by Holt, Edgar, and Firth.[61] If platinum and palladium dissolve hydrogen to some extent, the passage of carbon monoxide through heated iron cannot be attributed to adsorption. At present it is not possible to say whether an iron carbonyl plays any part in the diffusion or not. In the case of platinum and oxygen

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[56] *Zeit. phys. Chem.*, **74**, 641 (1910).

[57] For other discussions, see Masson, *Proc. Roy. Soc.*, **74**, 251 (1904); Davis, *Jour. Chem. Soc.*, **91**, 1066 (1907); Geddes, *Drude's Ann.*, **29**, 797 (1907); Wöhler, Pluddemann and Wöhler, *Zeit. phys. Chem.*, **62**, 670 (1908); Homfray, *Zeit. phys. Chem.*, **74**, 139, 687 (1910).

[58] Cf. Bose, *Zeit. phys. Chem.*, **34**, 708 (1900).

[59] Ramsay, Mond and Shields, *Ibid.*, **19**, 40 (1896); **25**, 657 (1898).

[60] Paal and Gerum, *Ber. deutsch. chem. Ges.*, **41**, 805 (1908).

[61] *Zeit. phys. Chem.*, **82**, 513 (1913).

Ramsay, Mond, and Shields[62] consider that most of the oxygen taken up forms $Pt(OH)_2$. They point out that Thomsen obtained an evolution of heat of 17,900 calories for the reaction $Pt + O = H_2O$, while they find 17,600 calories for the so-called adsorption of sixteen grammes of oxygen by platinum.

In view of the impermeability of rubber to water and its permeability to pyridine, it is hard to see how the permeability can be a question primarily of adsorption. I think that we must assume that carbon dioxide, pyridine, etc., actually dissolve in rubber.

While the equation $x/m = kp$ is a special case of the equation $(x/m)^n = kp$, where $n = 1$, and therefore may hold even in cases of adsorption, it is also the simplest case of Henry's law for the solubility of gases in liquids. Reychler[63] found that the amount of carbon dioxide taken up by blood charcoal was proportional to the partial pressure of the carbon dioxide in the vapor phase. The data are given in Table V. It does not seem probable that CO_2 dissolves in carbon, and I prefer to consider this a case of adsorption where the exponential factor happens to be unity. This view is confirmed by the fact that Geddes obtained very different relations for the adsorption of CO_2 by charcoal at 31° (Table IV).

TABLE V.

Adsorption of Carbon Dioxide by Blood Charcoal.

Formula $x/p = 0.00024$.
x = millimols CO_2 per gramme charcoal.
p = partial pressure in mm. Hg.
Temperature 20°

p	x	k	p	x	k
613.1	0.1461	0.00024	337.7	0.0855	0.00025
611.1	0.1424	0.00023	325.5	0.0808	0.00025
605	0.1320	0.00022	312.2	0.0706	0.00023
453.1	0.1014	0.00022	229	0.0560	0.00024
437.2	0.1086	0.00025	221.2	0.0523	0.00023
435.2	0.1063	0.00024	176	0.0452	0.00026
348.5	0.0844	0.00024	170.2	0.0451	0.00026
339	0.088	0.00026		mean	0.00024

Reychler also found that the amount of carbon dioxide taken up by rubber was proportional to the pressure over a narrow range of pressures. This may well be a case of solution of CO_2 in rubber.

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[62] *Ibid.*, **25**, 684 (1898).

[63] "Van Bemmelen Gedenkboek," 55 (1910).

CATALYTIC ACTION OF SOLIDS ON GASES.

The increased concentration at the surface of a solid will necessarily cause an increase in reaction velocity as a result of adsorption quite apart from any special catalytic action that the solid may exert. Nobody has ever compressed a mixture of oxyhydrogen gas so that it occupies the volume of liquid water, and consequently it is possible that the ignition of hydrogen and oxygen by spongy platinum may be due solely to the increased concentration. On the other hand, the fact that charcoal has very little effect in causing hydrogen and oxygen to combine indicates that some other factor is important in addition to increased surface concentration. In the case of SO_2 and O_2 Hempel[64] obtained a yield of 65 per cent. SO_3 without any catalytic agent by working at a pressure of thirty to forty atmospheres. Calvert[65] found that oxygen adsorbed by charcoal will burn ethyl alcohol to acetic acid, and ethylene to carbon dioxide and water. Damoiseau[66] showed that purified blood charcoal acted as a catalytic agent at 250° to 400°, causing the chlorination of ethyl chloride to hexachlorethane. Paal and Schwarz[67] have polymerized acetylene with platinum. The decomposition of carbon monoxide into carbon and carbon dioxide at nickel and cobalt surfaces[68] is another case in which it is possible, though not proved, that the reaction velocity depends primarily on the increase in surface concentration.

We can now consider the theory of cases in which special catalytic action occurs. Since we have adsorption from a gaseous mixture, we may also have selective adsorption of the reaction products, and this may cause one reaction to predominate at the expense of another. It is usually assumed that a catalytic agent cannot displace the equilibrium;[69] but this conclusion is necessarily true only when equilibrium is reached fairly rapidly in the gas phase. A solvent may accelerate a reaction and is therefore a catalytic agent. It may, and usually does, displace equilibrium, as in the case of nitrogen peroxide.[70] Hydrochloric acid is highly dissociated in water, but not in most solvents. If we have a reaction which takes place extremely slowly in the vapor phase and relatively rapidly in or at the surface of a solid catalytic agent, we may consider the adsorbing surface as equivalent to a solvent,[71] since we shall have the equilibrium in or at the surface, which corresponds to the surface, and which will not necessarily correspond with the theoretical equilibrium in the vapor phase. When the reaction products diffuse from the surface into the vapor phase they do not react by definition, and consequently we get in the vapor phase an apparent equilibrium corresponding to the surface conditions and which may vary markedly with different solid catalytic agents. Where two different reactions are possible, a given solid catalytic agent will increase the yield of the reaction products which are adsorbed the most strongly. Thus hydrogen is adsorbed by pulverulent nickel, platinum, or copper, and water vapor by pulverulent alumina.[72] As one might expect, alcohol is decomposed nearly quantitatively into acetaldehyde and hydrogen when passed over heated nickel or copper[73] and nearly quantitatively to ethylene and water when passed over heated alumina[74] or silica.[75] When titanium oxide is used as catalytic agent, both reactions take place simultaneously, and a yield of 84 per cent. C_2H_4 and 16 per cent. H_2 can be obtained under certain conditions. This should mean that titanium oxide adsorbs both water and hydrogen. This can be shown indirectly. When a mixture of alcohol and water vapor is passed over heated titanium oxide, the presence of the water vapor decreases the ethylene formation and there is an increased relative yield of hydrogen.[76] Conversely, there is an increased relative yield of ethylene if hydrogen is mixed with the alcohol vapor. If methane and hydrogen are heated with oxygen in presence of platinum or palladium, the hydrogen burns first,[77] whereas in borosilicate glass bulbs methane burns[78] before hydrogen.[79]

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[64] *Ber. deutsch. chem. Ges.*, **23**, 445 (1890).

[65] *Jour. Chem. Soc.*, **20**, 293 (1867).

[66] *Comptes rendus*, **73**, 60 (1876).

[67] *Ber deutsch. chem. Ges.*, **48**, 1195 (1915).

[68] Schenck and Zimmermann, *Ibid.*, **35**, 1231 (1903); Smits and Wolff, *Zeit. phys. Chem.*, **45**, 199 (1903).

[69] Van't Hoff, "Lectures on Theoretical Physical Chemistry," 215 (1898); Ostwald, *Zeit. Elektrochemie*, **7**, 998 (1901).

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[70] Cundall, *Jour. Chem. Soc.*, **59**, 1076 (1889); **67**, 794 (189?).

[71] Bancroft, *Jour. Phys. Chem.*, **21**, 588 (1917).

[72] Johnson, *Jour. Am. Chem. Soc.*, **34**, 911 (1912).

[73] Sabatier and Senderens, *Comptes rendus*, **136**, 738, 921, 936, 983 (1903).

[74] Ipatieff, *Ber. deutsch. chem. Ges.*, **34**, 3579 (1901); **35**, 1047, 1057 (1902); **36**, 1990, 2003, 2014, 2016 (1903).

[75] Sabatier and Senderens, *Comptes rendus*, **146**, 125 (1906).

[76] Engelder, *Jour. Phys. Chem.*, **21**, 676 (1917).

If a strongly adsorbed gas is added to a reacting mixture, it may cut down the adsorption of the reacting substances so much that the reaction comes practically to a standstill. Lunge and Harbeck[80] found that traces of carbon monoxide destroyed the catalytic action of platinum black on a mixture of hydrogen and ethylene. This poisoning of the catalytic agent, as it is called, is a very serious matter in many technical processes. If the reaction products are not removed sufficiently rapidly they will decrease the adsorption of the reacting substances and therefore retard the reaction. Sulphur trioxide[81] may have this effect in the contact sulphuric acid process.

Another set of reactions deserves mention here: the decomposition of arsenic hydride, antimony hydride, etc., where the reaction takes place chiefly at the surface of the containing vessel and not in the mass of the gas. To take a single case, the rate of decomposition of antimony, SbH_3 is accelerated by the presence of metallic antimony.[82] If we assume that antimony adsorbs antimony or tends to make antimony vapor condense upon it, the catalytic action follows at once. Lewis[83] has shown that the decomposition of silver oxide into silver and oxygen is accelerated by silver. At first sight this looks like the catalytic decomposition of one solid by another; but it seems impossible that the silver should act at a distance. It is probable, therefore, that we are really dealing with the decomposition of silver oxide vapor, in which case the reaction differs only in degree from the decomposition of stibnine. Taylor and Hulett[84] have shown that the decomposition of mercuric oxide is facilitated by finely divided platinum, ferric oxide, manganese dioxide, and cadmium oxide, but not by stannic oxide or alumina. While this is undoubtedly an adsorption phenomenon, the details are not sufficient to enable us to account satisfactorily for the results.

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[77] Henry, *Phil. Mag.*, **65**, 269 (1825); Hempel, *Ber. deutsch. chem. Ges.*, **12**, 1006 (1879).

[78] Bone, *Jour. Chem. Soc.*, **85**, 694 (1904).

[79] Bancroft, *Jour. Phys. Chem.*, **21**, 661 (1917).

[80] *Zeit. anorg. Chem.*, **16**, 50 (1898).

[81] Bodländer and Köppen, *Zeit. Elektrochemie*, **9**, 566 (1903); Berl, *Zeit. anorg. Chem.*, **44**, 267 (1905); Bodenstein, *Zeit. phys. Chem.*, **60**, 61 (1907).

[82] Stock and Guttmann, *Ber. deutsch. chem. Ges.*, **37**, 901; Bodenstein, 1361 (1907).

[83] *Zeit. phys. Chem.*, **52**, 310 (1905).

[84] *Jour. Phys. Chem.*, **17**, 568 (1913).

ADSORPTION OF GASES OR VAPORS BY LIQUIDS.

Since a gas or vapor may be adsorbed by a solid, one might expect to find selective adsorption by a liquid as well, and this proves to be the case.[85] Lord Rayleigh[86] found that impinging drops of water did not necessarily coalesce. If they were slightly electrified they coalesced readily, while stronger electrification kept them apart. A film of adsorbed air keeps the uncharged drops from coming into actual contact, and a slight electrification removes this film sufficiently to permit coalescence. Highly charged drops repel each other, this effect becoming noticeable for drops of 1 mm. radius when charged to 0.0031 volts.[87]

When the water drops from an oar on the recover, we often get what are known as rolling drops,[88] which depend on the presence of adsorbed air and which are also sensitive to the presence of electrified substances. Since soap-bubbles are hollow drops, we should expect them to behave in some ways like liquid drops, though not necessarily like the drops of a pure liquid. It is possible to knock two bubbles together with considerable force without causing them to coalesce,[89] because of the presence of adsorbed air films on the surfaces. If the bubbles are electrified slightly they coalesce readily without bursting.

If a vapor is adsorbed by a liquid it will condense to a liquid film at a temperature above that of the normal dew-point. Cantor[90] showed that this could be realized experimentally with water and mercury. Clark[91] has made similar experiments, but they are not of much value, because he used olive oil as one of the liquids, and olive oil is not a well-defined and reproducible liquid.

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[85] Bancroft, *Jour. Phys. Chem.*, **20**, 1 (1916).

[86] *Proc. Roy. Soc.*, **28**, 406 (1879); **29**, 71 (1879); **34**, 130 (1882).

[87] Nipper, *Science*, **34**, 442 (1911).

[88] Kaiser, *Wied. Ann.*, **53**, 681 (1894).

[89] Boys, *Phil. Mag.* (5), **25**, 409 (1888).

[90] *Wied. Ann.*, **56**, 492 (1895).

[91] *Proc. Am. Acad.*, **41**, 361 (1906).

ADSORPTION OF LIQUIDS BY SOLIDS.

Just as we have selective adsorption of a gas or a vapor by a solid so we get selective adsorption of a liquid by a solid. If a liquid is adsorbed at a solid surface, it forms a liquid film there, and we say that it wets the solid. If a liquid is not adsorbed by a solid it does not wet the latter. There has been a good deal of question whether the liquid meets the wall at a definite angle—the contact angle—or whether the contact angle is zero. Lord Rayleigh[92] states definitely that, in his opinion, the contact angle is zero. This must be true if we consider that the liquid is adsorbed by the solid. The reason that the rise of a liquid in a capillary tube is independent of the nature of the tube is because the rising liquid does not come in contact with the walls of the capillary tube at all.[93] We are really dealing with the rise in a liquid tube, and it consequently makes no difference what material is used to support the liquid tube. That this is the real explanation can be seen from the fact that concordant results are not obtained when a liquid is allowed to rise in a dry tube. To get good results it is important to immerse the tube in the liquid and then to raise it.[94]

For a liquid to wet a solid in the presence of air, the liquid must be adsorbed more strongly than the air and must displace it. Hoffmann[95] gives a number of details as to the slowness with which some liquids displace adsorbed air from certain solids. Lycopodium powder is distinctly difficult to wet. The floating of metallic powders or of pieces of metal on water is due to the slowness with which water wets them. The Cape Cod lighter consists of a porous stone set in a brass handle. When this is dipped into a can of kerosene the kerosene is sucked rapidly into the pores, displacing the air. The lighter is taken out, lighted, and placed under the logs of a wood fire. The adsorbed kerosene burns for about ten minutes, enabling one to do away with paper and even with kindlings. Solidified bromine[96] has been used for analytical purposes. It consists of siliceous earth saturated with bromine which can be driven out by heat. Of more technical importance is the adsorption of fused magnetite by chromite.[97] The straight magnetite arc flickers badly, but this can be overcome by mixing the magnetite with some more refractory material, such as chromite. The chromite remains solid and holds the melted magnetite like a sponge. In this way these arcs have been made steady and thereby suitable for industrial use.

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[92] *Scientific Papers*, **3**, 393 (1902).

[93] Fayleigh, *Scientific Papers*, **3**, 421 (1902).

[94] For a discussion of the experiments of Bigelow and Hunter, see Bancroft, *Jour. Phys. Chem.*, **21**, 407 (1917).

[95] *Zeit. phys. Chem.*, **83**, 385 (1913).

[96] Brand, *Jour. Chem. Soc.*, **52**, 688 (1887); cf. Thorp, "Outlines of Industrial Chemistry," 251 (1916).

The adsorption of a liquid film may introduce quite an error in the determination of the specific gravity of solids when these latter are in a finely divided state. As long ago as 1848, Rose[98] pointed out that platinum in the state of foil has a specific gravity between 21 and 22, while a value above 26 was found for platinum precipitated from the chloride by sodium carbonate and sugar. He explained that the solid is not weighed alone in water, but in conjunction with a film of condensed water. The loss experienced by the solid in water is therefore diminished and the apparent specific gravity increased.

It was Edward Lear who wrote about the Jumblies that went to sea in a sieve. We do not yet go to sea in a sieve ourselves, but we can carry water in one. If we take a fine-meshed metal sieve and oil the meshes, air can still pass readily through the holes; but water does not wet the wires, and consequently surface tension prevents it from passing through the holes.[99] We can carry water in such a sieve if we do not fill it too full; but an oiled sieve is not a perfect substitute for a pail. The principle, however, has received an important technical application in the shower-proofing of textile fabrics.[100] If the fibers of a closely woven fabric are coated with some water-repellent hydrocarbon or wax or with a water-repellent salt, the fabric will be porous to air, but will shed water up to a certain point. If the water is once forced through the pores, either by pressure or friction, the rain will afterward pass through at that point. This is why a tent will leak in a rain if one touches the canvas with a finger. Awnings on a boat usually leak where they rest on a wooden or iron support. There is always enough wind or vibration to be equivalent to the touching of the tent with the finger. For the same reason a tent is apt to leak around the pole. The reverse case is to be seen in the ordinary water-wings. They are made of a fine-meshed fabric which is first thoroughly wetted, so that a film of water is formed in the pores. The strength of this reënforced water film is so great relatively that one can blow up the water-wings without the air escaping, and the water-wings will support a grown person without difficulty.

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[97] Steinmetz, "Radiation, Light, and Illumination," 110 (1909).

[98] *Pogg. Ann.*, **73**, 1 (1848); *Jour. Chem. Soc.*, **1**, 182 (1879).

[99] Chwolson, *Lehrbuch der Physik*, **1** iii, 613 (1907).

[100] Weber, *Jour. Soc. Dyers and Colourists*, **17**, 146 (1901).

Since the adsorption of liquids by solids is selective, it follows that a given solid will adsorb one liquid more than a second liquid. Consequently the first liquid will displace the second from contact with the solid. No systematic study of this phenomenon seems to have been made, but we know that kerosene will displace water in contact with copper, and that water will displace kerosene in contact with quartz,[101] while alcohol will displace oil in contact with metal,[102] and linseed oil [103] will displace water in contact with white lead. The whole process of ore flotation depends on the fact that the ore adsorbs oil more strongly than does the gangue. According to these facts one should use a rag dipped in alcohol with which to wipe off a lamp, and it is for these reasons that we cover metal surfaces with vaseline or with a heavy oil to prevent rusting. In the kitchen people wet the moulds before putting in corn-starch or gelatine, and they butter the pans before making fudge, or grease the griddles before making flapjacks. Aluminum griddles do not need to be greased, because the air in the oxide film keeps the cakes from sticking. In making pottery, it is the practice to oil the dies when making dust-pressed ware.[104] Infusorial earth is excellent [105] for cleaning glass plates for photographic purposes. Even very greasy plates become clean very rapidly when rubbed with infusorial earth moistened with water. Some of the methods for removing grease spots from clothes depend on selective adsorption.[106] Actors use grease paints to prevent too marked adsorption.

There are almost no quantitative data on selective adsorption. Graham [107] made a few rough measurements on the selective adsorption of liquids by palladium. A piece of foil was immersed in a liquid for an hour and afterward dried by pressure for a few seconds between folds of blotting-paper. One thousand parts of palladium foil were found to retain 1.18 parts of water, 5.5 of alcohol, 1.7 of ether, 0.54 of acetone, 4.5 of glycerine, 3.5 of benzene, 10.2 of castor oil, and 18.1 of oil of sweet almonds. Quite recently Mathers [108] has shown that lead adsorbs certain essential oils from aqueous solution.

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[101] Hofman, *Zeit. phys. Chem.*, **83**, 385 (1913).

[102] Pockels, *Wied. Ann.*, **67**, 669 (1899).

[103] Cruickshank Smith, "The Manufacture of Paint," 92 (1915).

[104] Simcoe and Smith, *Trans. Am. Ceramic Soc.*, **14**, 558, 567 (1912).

[105] Koller, "The Utilization of Waste Products," 310 (1915).

[106] Lake, *Jour. Phys. Chem.*, **20**, 761 (1916).

[107] *Jour. Chem. Soc.*, **20**, 275 (1867).

Since the adsorption is selective, a vapor or liquid will be adsorbed more readily by one surface than by another. A striking application of this is to be found in the old daguerreotype process. The latent image is formed on a plate of silver coated with silver iodide, and it is developed by means of mercury vapor. The mercury condenses in the places which have been exposed to light. I have seen a patched cement floor on which moisture condensed so markedly on the weathered portion that it seemed as though a pipe had broken under the floor.

If the adsorption is very marked we may get intense strains.[109] Gelatine is adsorbed so strongly by glass that the gelatine film in drying will often tear loose fragments of glass. On the other hand, it does not adhere to plates of mica or calcite. With agar-agar the initial concentration appears to be important. Certain agar-agar jellies will adhere readily to glass, while others apparently do not. People have claimed that the substitution of agar-agar for gelatine in photographic plates would be impossible on a technical scale, because the agar-agar film would slip off if the plates were set vertically to dry. It is probable that this difficulty would be overcome if that were the only drawback.

The whole theory of adhesives depends in part on the fact that the cementing material adheres strongly to the two surfaces and hardens there. It is therefore possible that one agglutinant may be useful for a number of different materials, such as wood, glass, metal, ivory, etc., while others give good results only with special materials. Since the books give different recipes for cements for glass, cements for metals, cements for metals and glass, etc., the differences in adsorption are real ones, though nobody has ever made a careful study of agglutinants from this point of view.

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[108] Private communication.

[109] Graham, *Jour. Chem. Soc.*, 17, 320 (1864).

A good glue joint in wood will easily stand a strain of 6000 pounds per square inch. We are quite familiar with this, but we do not always realize that the tensile strength of liquid water is pretty high if a decrease in the cross-section can be prevented. Budgett[110] found a maximum breaking strength of about 87 pounds per square inch for steel end-gauges held together by a water film. On the assumption that the water occupied only one-tenth of the surface, this gives a tensile strength of nearly 900 pounds per square inch, or sixty atmospheres. As far back as 1850 Berthelot[111] filled a glass tube nearly full of liquid, removed the air, sealed the tube, heated the tube until it was entirely full of liquid, and allowed the whole thing to cool. The liquid continued to fill the tube until the volume was larger than it should be for the temperature by 1/420 in the case of water, 1/93 in the case of alcohol, and 1/50 in the case of ether. This indicates a breaking strain of about 50 atmospheres for water and over 100 atmospheres for alcohol and ether. Worthington[112] obtained 17 atmospheres for alcohol. Stefan[113] and Tumlirz[114] consider that the calculated internal pressure of a liquid is a measure of the theoretical tensile strength, and they obtain in this way a value for alcohol[115] of about 2000 atmospheres.

The adsorption of water vapor by gelatine presents some peculiarities. Working in Ostwald's laboratory, von Schroeder[116] found that gelatine contained over a thousand per cent. of water when immersed in liquid water and less than 400 per cent. when in saturated water vapor at the same temperature. From these and other experiments von Schroeder concluded that the vapor pressure of water in gelatine must be higher than that of pure water, because water distills from the gelatine to the vapor phase. The reason for this unexpected phenomenon is probably that gelatine has a cellular structure.[117] If a dry paper bag be placed in a space saturated with vapor water the paper will adsorb a certain amount of water, but there will be little or no tendency for the bag to fill with liquid water. If a similar bag is immersed in liquid water the paper will take up water as before, but water will also pass into the bag and fill it. If the bag is then lifted into the vapor phase and if the bag is so constructed that the actual dripping is negligible, the water will distill from the curved surface of the bag to the plane surface in the containing vessel. The smaller the bag is the greater will be the curvature of the water surface and consequently the higher the vapor pressure. With the microscopic spaces to be assumed in solidified gelatine, the vapor pressure of the drops of water will be enough higher to counterbalance the differences of levels in von Schroeder's experiments.

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[110] *Proc. Roy. Soc.*, **82** A, 25 (1912).

[111] *Ann. Chim. Phys.* (3), **30**, 232 (1850).

[112] *Phil. Trans.*, **183** A, 355 (1892).

[113] *Wied. Ann.*, **29**, 685 (1896).

[114] *Sitzungsber. Akad. Wiss. Wien.* **100** II a, 837 (1900); **110** II a, 437 (1901).

[115] Cf. Hulett, *Zeit. phys. Chem.*, **42**, 353 (1903).

[116] *Zeit. phys. Chem.*, **45**, 109 (1903).

[117] Bancroft, *Jour. Phys. Chem.*, **16**, 395 (1912).

While this explanation accounts for the phenomena, provided gelatine really has a cellular structure—a point which is not yet generally accepted—it is superfluous if the facts are not as stated. Wolff and Buchner[118] claim that the loss of water, when gelatine is placed in the vapor phase, is merely due to experimental error. They have certainly shown the possibility of error in von Schroeder's results, but they did no experiments involving as much error as one must assume if von Schroeder's data are worthless. The whole matter is therefore "up in the air" for the present.

There are other substances which seem to behave like gelatine, though no experiments like von Schroeder's have been tried. Schwalbe[119] states that cotton cellulose takes up 21 per cent. moisture in presence of saturated water vapor. Masson and Richards[120] find 17.7 per cent. adsorbed moisture when the vapor phase is 97 per cent. saturated. By extrapolation to 100 per cent. this might easily give about 21 per cent. moisture; but Masson and Richards incline to the view that the curve is asymptotic, in which case the value would be infinite, which seems absurd. Vignon[121] finds that one gram of cotton takes up about five grams of liquid water, while a fine-grained sponge will hold thirty grams of water per gram of sponge, and a coarse-grained sponge only about six grams. Leighton[122] states that absorbent cotton will hold four grams of water per gram of cotton when centrifuged at 4000 revolutions per minute. Some of this water is held in capillary spaces; some is adsorbed on the surface of the cotton; a part is probably dissolved in the cotton, and some may be held in cells. We have no satisfactory way of differentiating between these possibilities.

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[118] *Zeit. phys. Chem.*, **89**, 271 (1915).
[119] "Die Chemie der Cellulose," 10 (1911).
[120] *Proc. Roy. Soc.*, **79** A, 421 (1905).
[121] *Comptes rendus*, **127**, 73 (1893).
[122] *Jour. Phys. Chem.*, **20**, 32 (1916).

Dry caseine takes up about 1.25 grams of water per gram of caseine.[123] Infusorial earth [124] is able to take up more than double its weight of nitroglycerin without running.[125] Fibrous peat, fresh from the bog, may contain 90 per cent. of water, and Sphagnum moss may imbibe as much as two hundred times its own weight of water,[126] which is the reason that this moss is used largely in the trenches for dressing wounds. Attention might perhaps be called here to Meissner's experiments on the heat developed when powders are wetted by liquids.[127] He found that there was no appreciable difference in the heat evolved when the water was above or below 4°. His quantitative results were rather discouraging, however, because he found no apparent relation between the amounts of heat evolved and the amounts of powder taken, which must be the result of experimental error.

ADSORPTION OF SOLIDS BY SOLIDS.

Dried glue may be considered either as a solid or as a supercooled liquid. If we consider it as a solid, then the adsorption of gelatine by glass is a case of adsorption of a solid by a solid. It is more satisfactory to cite cases where both substances are unquestionably solid. If a metal is polished with rouge which is not kept sufficiently moist, the rouge adheres so firmly to the metal surface [128] that it cannot be removed without spoiling the polish. In blue powder we have grains of zinc coated with zinc oxide which adheres even when the zinc is melted. Aluminum and nickel are always coated with solid surface films which have marked effects on the properties of the metals. All patines on metals involve adsorption; otherwise they would come off readily.

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[123] Van Slyke and Publow, "Science and Practice of Cheese-Making," 179 (1913).

[124] Koller, "Utilization of Water Products," 310 (1915).

[125] Kressmann, *Met. Chem. Eng.*, **14**, 372 (1916).

[126] "Percy's Metallurgy: Fuel," 208 (1875).

[127] *Wied. Ann.*, **29**, 114 (1886).

[128] Desch, "Metallographie," 210 (1914).

Passive iron owes its peculiar properties to the adsorption and stabilization of a higher oxide,[129] either FeO_2 or FeO_3. The latent image on photographic plates is due to an adsorption of silver by silver bromide.[130]

We get an apparent case of adsorption of a solid by a solid if we shake a moderately coarse powder with a much finer powder. Instead of the finer powder filling the voids in the space occupied by the coarse powder the former tends to coat the latter.[131] With a given mixture of thoria and tungsten Fink obtained a black powder which conducted electricity when the tungsten was finer than the thoria, and a white non-conducting powder when the reverse was the case. Briggs found that a mixture of 0.032 gram Prussian blue with 10 grams dolomite varied from deep blue to nearly white, depending on the relative sizes of the two powders. When 10 grams of dolomite was ground coarser than 40 mesh, 8 milligrams of lampblack produced a certain shade. When the dolomite was ground so that it all passed a 200-mesh sieve, 654 milligrams of lampblack, or over eighty times as much, were needed to produce approximately the same tint. This behavior of powders is of great importance when using inert fillers in mixed paints.[132]

If one strews lycopodium powder over the surface of water and then puts one's finger into the water, the lycopodium powder sticks to the finger and keeps it from being wetted.[133] A coarse powder kept in a bottle will fall to the bottom under the influence of gravity, while a very fine powder will stick to the walls of the bottle, discoloring them. It seems probable that the use of face powder is merely a special case of a very fine powder adhering to a curved surface. The retarding effect of gypsum on the rate of setting on Portland cement is probably due to the fact that the finer gypsum powder coats the coarser cement powder and acts to some extent as a protecting film.

In all of these cases the powders do not come in actual contact, but are separated by a film of air, which, however, holds them together, thus behaving like a liquid film. Traces of moisture will, of course, increase the adhesion, as with sugar on blueberries. Stoney[134] has shown that very fine powder in a metal dish becomes extremely mobile when the dish is hotter than the powder. The converse seems also to be true, that the powder is not mobile when it is hotter than the curved surface, because Tammann[135] finds that hot wood-charcoal powder adheres to a cold rod of glass or metal, but falls off when powder and rod are of the same temperature. Tammann was evidently working with particles coarse enough to fall off under the influence of gravity except when special conditions prevailed.

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[129] Bennett and Burnham, *Jour. Phys. Chem.*, **21**, 107 (1917).

[130] Bancroft, *Ibid.*, **17**, 93 (1913).

[131] Fink, *Ibid.*, **21**, 32 (1917).

[132] Toch, "The Chemistry and Technology of Paints," 113, 138 (1916).

[133] Ehrenberg and Schultzer, *Zeit. Kolloidchemie*, **15**, 183 (1914).

ADSORPTION OF LIQUIDS BY LIQUIDS.

The spreading of one liquid over another is usually considered to depend on the relative surface tensions, but this is not a very satisfactory way of looking at things.[136] The simplest way is to treat it as a case of adsorption. If oil is adsorbed by water it wets the water and spreads over the surface. The adsorbed layer may vary from 2 to 200[137] $\mu\mu$ with different oils.[138] At greater thicknesses the oil may tear loose from the oiled surface of the water, drawing up into drops under the influence of surface tension. At still greater thicknesses the drops coalesce to form a liquid layer having the properties of matter in mass. If the oil is not adsorbed by water there is no spreading. This case seems to have been realized by Hardy.[139]

ADSORPTION OF SOLIDS BY LIQUIDS.

A solid which is wetted by a liquid adheres to that liquid. With two liquids and one solid we shall get selective adsorption of the solid, and this leads to some interesting results which have been studied in detail by Hofmann.[140] If finely divided red lead is shaken with water and benzene or chloroform, the red lead adheres to the surface of the benzene or chloroform, making a practically continuous coating around the organic liquid, provided proper relative amounts of red lead and organic liquid are taken.

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[134] *Phil. Mag.* (5), **4**, 443 (1877).

[135] *Drude's Ann.*, **18**, 856 (1905).

[136] Rayleigh, *Scientific Papers*, **3**, 354, 413, 416 (1902).

[137] μ = micron = thousandth millimeter; $\mu\mu$ = millionth millimeter.

[138] Hardy, *Proc. Roy. Soc.*, **86** A, 612 (1912).

[139] *Proc. Roy. Soc.*, **86** A, 632 (1912).

[140] *Zeit. phys. Chem.*, **83**, 385 (1913).

The theory of the phenomenon has been given by Des Coudres.[141] If water displaces benzene or chloroform from the surface of a given solid, the solid will tend to stay in the water phase; if benzene or chloroform displaces water, the solid tends to stay in the benzene or chloroform phase; if neither liquid displaces the other completely, the solid will tend to pass into the dineric[142] interface. The solid particles stay in the interface or in the upper liquid layer only when they are fairly fine. In Table VI are given some of Hofmann's results. The letter *w* means that the solid goes nearly completed into the water phase, while *o* denotes that it goes almost completely into the organic liquid, and *s* that the powder collects nearly quantitatively in the interface. Two letters, such as *sw*, means that the powder goes partly into the interface and somewhat less into the water phase; the use of parentheses, *s*(*w*) or *s*(*o*), signifies that there is a good deal more powder in the interface than in the bracketed phase. Ben-

TABLE VI.

	Water and ether	Chloroform	Butyl alcohol	Benzene	Kerosene	Amyl alcohol	Paraffin oil
$CaSO_4$	*w*	*w*	*w*	*w*	*w*	*w*	*w*
SnO_2	*w*(*s*)	*ws*	*ws*	*s*(*w*)	*s*(*w*)	*sw*–	*sw*
$Al(OH)_3$	*w*(*s*)	*ws*	*ws*	*s*	*s*(*w*?)	*sw*	*s*(*w*)
SnS	*ws*	*ws*	*ws*	*s*(*w*)	*s*(*w*)	*s*	*ws*
$BaSO_4$	*ws*	*ws*	*ws*	*s*	*s*	*s*(*w*?)	*s*(*w*?)
ZnS	*w*(*s*)	*ws*	*ws*	*s*	*s*(*w*?)	*s*	*s*(*w*?)
ZnO	*ws*	*ws*	*s*(*w*)	*s*	*s*	*s*	*s*
$CaCO_3$	*ws*	*ws*	*s*	*s*	*s*	*s*	*s*
$Mg(OH)_2$	*s*(*w*?)	*ws*	*s*	*s*	*s*	*s*(*w*)	*sw*
Al	*sw*	*s*(*w*)	*s*(*w*)	*s*	*s*	*s*(*w*)	*s*
$BaCO_3$	*ws*	*ws*	*s*	*s*	*s*	*sw*	*s*
CuS	*ws*	*s*(*w*)	*s*	*s*	*s*	*s*	*s*
$PbCrO_4$	*ws*	*s*(*w*?)	*s*	*s*	*s*	*s*	*s*
Cu_2O ?	*ws*	*s*	*s*	*s*	*s*	*s*	*s*
MoS_2	*s*(*w*?)	*s*	*s*	*s*	*s*	*s*	*s*
PbS	*ws*	*s*	*s*	*s*	*s*	*s*	*s*
Fe_3O_4	*ws*	*s*	*s*	*s*	*s*	*s*	*s*
$BaCrO_4$	*ws*	*s*	*s*	*s*	*s*	*s*	*s*
Pb_3O_4	*sw*	*s*	*s*	*s*	*s*	*s*	*s*
C	*sw*	*s*	*s*	*s*	*s*	*s*	*s*
PbI_2	*s*	*s*	*os*	*s*	*s*	*os*	*s*
HgS	*s*	*s*	*s*	*s*	*s*	*s*	*s*
HgO	*s*	*s*	*s*	*s*	*s*	*s*	*s*
HgI_2	*s*	*s*	*s*	*s*	*s*	*o*	*os*
AgI	*s*	*s*	*o*	*s*	*s*	*o*	*os*

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[141] *Arch. Entwicklungsmechanik*, 7, 325 (1898).

[142] Dineric means "two-liquid."

zene and xylene behave alike, so only one is given. In these experiments the powder was placed in water and then shaken with the organic liquid.

Similar results were obtained by Reinders[143] with colloidal solutions. Isobutyl alcohol was added to a colloidal gold solution obtained by reducing gold chloride with carbon monoxide. When the two liquids are shaken, the gold forms a thin film at the interface. This film is violet-blue to blue-green by transmitted light and golden by reflected light. A thin film forms between the isobutyl alcohol and the glass, and the gold concentrates in the dineric interface thus formed, making the alcohol appear uniformly gold-plated. With ether the gold film rises high above the level of the two liquids. With carbon bisulphide the adherent film of gold appears blue. When the carbon bisulphide is broken into drops by shaking, each drop appears blue. When a blue gold was obtained by reducing gold chloride with phosphorus dissolved in ether, the gold went into the dineric interface. When a brownish-red gold was obtained in this way, it remained in the water phase and showed no tendency to pass into the interface. This difference is undoubtedly due to an adsorption of something at the surface of the gold, because Reinders found that 0.005 per cent. gum arabic prevents colloidal gold from passing into the ether-water interphase. With carbon tetrachloride, carbon bisulphide, and benzene, the gold goes into the interface as before, but the gum arabic prevents its changing from red to blue.

Colloidal arsenic sulphide goes into the dineric interface with amyl alcohol or isobutyl alcohol, but stays in the water phase when carbon tetrachloride, benzene, or ether is the second liquid. India ink goes completely into the interface with amyl alcohol, carbon tetrachloride, or benzene; it goes partly into the interface with isobutyl alcohol, and stays entirely in the water phase when ether is the second liquid. When crystallized copper eosinate is placed in water and shaken with ether it goes entirely into the interface,[144] forming a film which resembles the purple skin of a grape by reason of the steel-blue color of the crystals.

An interesting experiment is to shake copper powder or aluminum powder with kerosene and water. The metallic powder goes into the kerosene and into the interface, producing an effect of molten copper or molten aluminum, as the case may be. When the bottle is allowed to stand after having been shaken, the metallic powder in the interface creeps up the side of the bottle above the surface of the liquid, rising higher if a little alcohol has been added. I have seen a metallic film rise two or three inches above the surface of the upper liquid phase. If too much copper or aluminum be added the kerosene cannot hold it all up, and a portion falls to the bottom, carrying drops of kerosene with it. The aluminum and copper powders on the market are coated with stearin, but this helps the experiment, though not essential to it.

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[143] *Zeit. Kolloidchemie*, **13**, 235 (1913).

[144] Gilbert, *Jour. Phys. Chem.*, **18**, 602 (1914).

White lead passes from water into linseed oil,[145] and this is made use of in preparing pulp-ground lead.[146] Zinc oxide, on the other hand, stays in the water phase. The Elmore bulk-oil process of ore flotation depends on the fact that some sulphide ores can be shaken out of the water phase by means of suitable oils, while the gangue remains in the water phase.

The readiness with which solid films form over the surface of mercury is well known to everybody. They are due to the adsorption of certain compounds of mercury or of baser metals. The substances causing the "flouring" of mercury are soluble in cyanide solution.

In this paper there has been given a discussion of: adsorption of gases and vapors by solids; catalytic action of solids on gases; adsorption of gases and vapors by liquids; adsorption of liquids by solids; adsorption of solids by solids; adsorption of liquids by liquids; adsorption of solids by liquids.

CORNELL UNIVERSITY.

Calorized Iron as an Element for Thermocouples. O. L. KOWALKE. (*Proceedings of the American Electrochemical Society,* October 3–6, 1917.)—There are available several thermocouples with iron as one of the elements which have high electromotive forces and are fairly constant, but have the disadvantage that the iron element oxidizes rapidly above 500° C. If iron could be protected from oxidation by some sort of a coating which would not greatly change the electromotive force, its usefulness as an element for thermocouples would be greatly extended. It has been shown by W. E. Rudder that "calorizing" iron, which consists in producing a rich aluminum alloy upon the surface of the metal, practically prevents oxidation below 1000° C.

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[145] J. Cruickshank Smith, "The Manufacture of Paint," 92 (1915).

[146] Holley, "Lead and Zinc Pigments," 71 (1909).

The author has compared the thermo-electromotive forces of couples of "calorized" iron-constantan with that of uncalorized iron-constantan. A sample of calorized iron wire from the General Electric Company gave the same thermo-electric potentials as uncalorized iron up to 1000° C. on repeated calibrations. A sample from the Brown Instrument Company gave slightly different potentials until heat-treated at 800° C., after which it gave similar results to other calorized wire. The author concludes that a heavy wire, lightly calorized, gives as constant results as uncalorized iron and has a much longer life.

The Expansion and Contraction of Concrete and Concrete Roads. A. T. GOLDBECK and F. H. JACKSON, JR. (*U. S. Department of Agriculture,* Bulletin No. 532, October 13, 1917.)—Observation of concrete roads shows that most of the irregularities of wear make their initial appearance at expansion joints and at transverse and longitudinal cracks. Soon after a crack is formed traffic begins to batter down the edges, and unless immediate and effective maintenance measures are adopted, each succeeding vhicle will act with greater destructive effect. Under such conditions and without proper maintenance, little time elapses before depressions are formed in the road surface which lessen the life of the road and render it decidedly unpleasant to the fast-moving traffic generally carried by concrete roads. Improperly maintained expansion joints wear in a manner similar to cracks, and the cost of their maintenance is dependent upon their frequence.

Cracks result when the tensile strength of the concrete has been exceeded, or compression cracks may be caused in rare instances by excessive expansion without proper provision for such a movement. Tension may occur in a concrete pavement as the result of settlement or upheaval, in which case the pavement is stressed as a slab, and, if overstressed, will crack on the tension side. Most transverse cracks, however, are caused by contraction due to decrease in temperature and drying out of water from the concrete. When the drainage is good and the sub-base not wet, the temperature effects seem to be most important. In very dry climates, shrinkage due to drying must be added to contraction due to fall in temperature. Temperature at time of construction of road should be considered in designing joints. Cold-weather construction requires a full allowance for temperature expansion, and, on wet sub-bases, for moisture expansion also. Hot-weather construction theoretically requires no joints at all, even on wet sub-bases, as the temperature contraction exceeds the moisture expansion. However, the difficulty of keeping the cracks clear probably renders joints inoperative.

THE ELECTRON THEORY.*

BY

WILLIAM ALBERT NOYES, Ph.D., LL.D.,
Director of the Chemical Laboratory, University of Illinois.

IT is only twenty years since Prof. J. J. Thomson first characterized accurately those atoms of negative electricity which we call electrons, but, as with most great discoveries, many lines of work and of thought, reaching back for more than a century, culminated in this discovery. It seems worth while to go back and pick up some of these threads and look at their relations.

On August 1, 1774, Priestley discovered oxygen. He called it dephlogistigated air, and explained its properties on the basis of the old theory of phlogiston. Lavoisier, in Paris, when he learned of this discovery, repeated the experiments and soon came to a clear view of the important part which the element plays in nature. He considered that compounds of oxygen with the non-metallic elements are acids and that the compounds with metallic elements are bases. These acid oxides and basic oxides, in turn, combine to form salts. The point in which we are interested is the notion that the acid oxides and basic oxides are binary compounds, and that salts are also binary compounds of a second order. About 1790, according to a tradition which is questioned, some frogs' legs which had been purchased for an invalid wife of the Italian physician, Galvani, were hung on brass hooks attached to an iron railing. One of Galvani's pupils noted a peculiar twitching of the frogs' legs and called Galvani's attention to it. Thus began the discovery and study of current electricity. I have found in an old chemistry this cut (Fig. 1) to illustrate Galvani's experiments. When the pieces of copper and zinc are brought into contact the current flows and the frogs' legs twitch into the second position.

Soon after, Volta, in Paris, invented the voltaic pile, by means of which much stronger currents could be obtained. This figure (Fig. 2), taken from an old chemistry published in 1846, shows one of these early galvanic batteries. Sir Humphry Davy used one of these batteries in London, about 1804, when he made his great discovery of the decomposition of potash and soda by the electric current. This discovery attracted his attention to the very intimate connection between electricity and chemical action, and led him to the proposal of the old electrochemical theory. This theory was further developed by Berzelius, and it dominated the minds of chemists for half a century.

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* Abstract of a paper presented at the meeting of the Section of Physics and Chemistry held Thursday, April 12, 1917.

According to this theory, the atoms of the elements have two poles, one positive and one negative, and each element is positive or negative, according to the relative amounts of the two charges. When two elements combine, the discharge between the positive pole of one and the negative pole of the other causes an evolution of heat. The resulting compound may still be positive, as in the case of a metal united with oxygen, or negative, as, for instance, the acid oxides. The union of the positive oxide with a negative oxide gives a salt. The intimate relation between the theory and Lavoisier's ideas about oxides and salts is apparent.

Fig. 1.

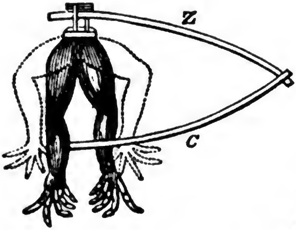
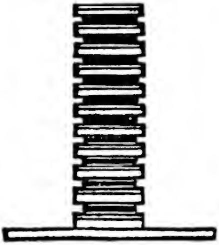


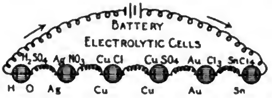
Fig. 2.



In 1833 Faraday discovered a method of measuring an electrical current by determining the quantities of hydrogen and oxygen liberated by passing the current through dilute sulphuric acid. He soon found that if the same current is passed through two electrolytes, as through dilute sulphuric acid and through a solution of copper sulphate in successive cells, the amounts of the elements liberated in the two cells will be in proportion to the chemical equivalents of the elements. Thus in the series of cells shown in Fig. 3, when one gramme (in round numbers) of hydrogen has been liberated in the first cell, 108 grammes of silver will have been deposited in the second, 63.6 grammes of copper in the third, 31.8 grammes of copper in the fourth, 65.7 grammes of gold in the fifth, and 29.5 grammes of tin in the sixth.

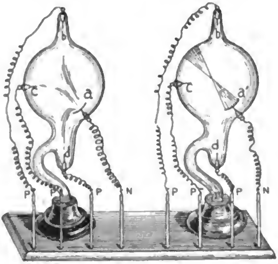
I do not think that Faraday grasped the full significance of this wonderful law which bears his name. It points very clearly to a definite unit quantity of electricity which is directly connected with those primary units of matter which we call atoms. It is not a unit of energy, since the energy absorbed in the decomposition of the different electrolytes is not the same. Helmholtz stated the logical inference from the law very clearly in his Faraday lecture in 1881. He said, "If we accept the hypothesis that elementary substances are composed of atoms, we cannot avoid the conclusion that electricity, positive as well as negative, is divided into definite elementary portions, which behave like atoms of electricity." This idea is very different from that in the theory of Berzelius, who considered that differences in affinity were caused by differences in the quantity of electricity in different atoms.

FIG. 3



The next advance seems rather a step backward than forward, as it consisted in the overthrow and complete abandonment of the old electrochemical theory. In that theory chlorine was always negative and hydrogen was always positive in their compounds. But Dumas showed that three derivatives of acetic acid could be prepared in which one, two, or three atoms of the positive hydrogen could be replaced by one, two, or three atoms of the negative chlorine, and yet the resulting compounds were monobasic acids resembling acetic acid in their salts and in their decompositions. In his attempts to explain these and other compounds on the basis of the electrochemical theory, Berzelius found himself more and more in conflict with well-established facts of organic chemistry, and, in spite of his tremendous authority as one of the leading chemists of his time, the chemical world gradually abandoned the dualistic point of view and accepted a unitary conception of chemical compounds. Then, beginning in the fifties, there came the period of the rapid development of the theories of valence and of structural organic chemistry. During this period, which lasts, with very little change, to the present time, the attempt to connect the forces which hold the atoms in combination with electrical forces in any definite way was almost completely abandoned. It is true that the terms "positive" and "negative" have been frequently used throughout the period, but they have been used in a wholly vague and indefinite manner, with no real thought of electrical properties in the atoms or groups to which they are applied.

FIG. 4.



As so often happens, the beginning of a return to an electrical theory of combination came from the study of phenomena in a different and, as it seemed at the time, wholly unrelated field. During the late seventies, Crookes busied himself with the study of electrical discharges through highly rarefied gases. The phenomena which he discovered were so strange and startling that he spoke freely of a "fourth state" of matter. The physicists and chemists of the time were disposed to look on the expression as somewhat sensational, but the event has shown that he was nearer right than his critics. The phenomena of most interest to us are those of the discharge from the cathode, or negative pole, through a tube in which the pressure of the residual gas has been reduced to one-millionth of an atmosphere. Under such conditions rays are shot out in straight lines perpendicular to the surface of the cathode, and when they impinge on the glass opposite they produce a beautiful green fluorescence and give rise to the X-rays, though those rays were not discovered till some fifteen years later. Crookes showed that this "radiant matter," as he called it almost with the vision of a prophet, travels straight across the tube, irrespective of the location of the anode. Thus in the bulb containing rarefied air, shown at the left in the figure (Fig. 4), the current from an induction coil will pass in a curved path from the negative pole *a* to any one of the positive poles, *b*, *c*, or *d*, to which the positive pole of the coil is connected. When the pressure within the bulb is reduced to a millionth of an atmosphere or less, the cathode rays are shot out at right angles to the surface of the negative pole and impinge on the glass opposite, irrespective of the attachment of the positive pole of the coil to the top, bottom, or side of the bulb. This effect is shown at the right of the figure. Crookes also showed that an opaque object in the path of the rays casts a shadow, as shown in Fig. 5. By a very ingenious apparatus he caused the stream of "radiant matter" (electrons) to drive a little windmill (Fig. 6). When a magnet is brought near the

FIG. 5.

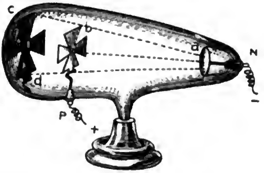
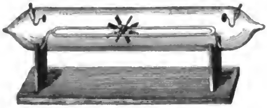


FIG. 6.



tube the rays are deflected in such a manner as to show that the rays consist of negative, charged particles (Fig. 7).

By means of this apparatus (Fig. 8), which has been kindly loaned by my friend, Professor Knipp, of the University of Illinois, I can show you the stream of electrons sent out by the cathode, *C*. The bulb, *B*, is filled with charcoal. When this is immersed in liquid air the charcoal absorbs nearly all of the minute quantity of air which has been left in the apparatus, leaving a very high vacuum, which readily allows the passage of the cathode rays across the bulb, *N*. When I place this horseshoe magnet over the tube near the cathode the rays are bent downward, as you see. When the poles of the magnet are reversed, the rays are bent upward. The cathode is perforated and luminous; positive rays, which are called canal rays, are sent across the bulb, *M*. You see that these positive rays are not deflected by the magnet. We shall come back to these later.

Fig. 7.

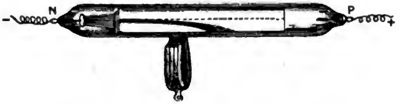
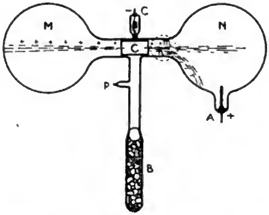


Fig. 8.

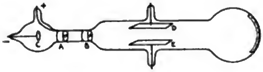


When the cathode rays strike the glass the X-rays discovered by Röntgen about 1890 are produced. In one place in his paper, published in *Chemical News* in 1879, Crookes speaks of this "radiant matter" shot from the cathode as belonging to the borderland between matter and energy. This seems almost a prophecy of the doctrine of modern physicists that the mass of an electron is dependent on its velocity. Indeed, some physicists seem to say that the *whole* of the mass is due to the velocity, though I confess to some difficulty in understanding what is meant by such a statement. Crookes also predicted that some of the most important discoveries of the future would be made in connection with the study of "radiant matter"—a prediction which has been fully verified.

In 1887 Arrhenius published his classical paper on electrolytic dissociation. This laid the foundation for a new electrochemistry which has avoided many of the difficulties of the older theory and which furnishes the only rational means we have for the study of many of the properties of solutions of electrolytes. It is now clear that in such solutions electrolytes separate more or less completely into atoms or groups bearing positive or negative charges.

In 1897 Prof. J. J. Thomson took up again the study of the cathode rays in the Crookes tubes. By means of the apparatus shown in Fig. 9 he showed that when static charges of opposite sign are applied to the plates *D* and *E*, the cathode rays passing through the narrow slits in *A* and *B* are attracted toward the positive plate, and this can be shown and measured by the motion of the spot of light falling on the scale at the end of the bulb. He then devised a very ingenious experiment in which he deflected the cathode rays into an insulated hollow vessel by an electromagnet. Knowing the capacity of the vessel, he could determine the quantity of electricity carried into it by the electrons in a given time. He then arranged to have the electrons fall on a thermocouple of known heat capacity, and determined the energy developed on stopping them. From the data obtained he calculated that the velocity of the particles was of the order of ten thousand miles a second, or even as high as one-tenth the velocity of light. The quantity of electricity carried by the particles was found to be very considerable in proportion to the heat

FIG. 9.



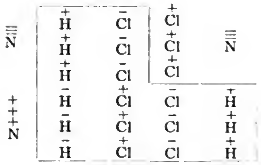
energy shown by the thermocouple. These facts seemed to allow for only two alternatives: either the mass of the particles is extremely small, or each particle must carry an enormous charge of electricity. Further experiments confirmed the choice of the first of these possibilities, and physicists are generally agreed that the mass of the electron is about one eighteen-hundredth part of the mass of a hydrogen atom. Physicists are not altogether agreed, however, as to whether this electromagnetic mass is the same in nature as the mass of an atom, which may be measured by reference to the force of gravity. If it is affected by gravity, an electron having a velocity of 10,000 kilometres a second would fall toward the earth possibly two millimetres in flying 800 kilometres, say as far as Cleveland. The difficulty of preparing a straight, evacuated tube of that length is evidently rather great, and we shall probably have to wait some time for experimental evidence on this point. The question has become one of unusual speculative interest in the light of the discussion by J. J. Thomson and the measurements of Kaufmann and Bucherer, which seem to show that the mass of the electron is wholly dependent on the velocity with which it moves.

In the light of Thomson's experiments, we may now say that Crookes's " radiant matter " consists, in reality, of atoms of negative electricity. Professor Thomson called these atoms corpuscles, but they are now universally known as electrons. A knowledge of the properties of these new atoms has given us quite a new conception of the nature of a current of electricity in metallic conductors.

It has become clear that atoms of the elements contain electrons, and that metals allow these electrons to pass readily from one atom to another in a regular flow which furnishes the current of electricity in metallic conductors. In electrolytic conduction, on the other hand, electrons are associated with the negative ions, and these pass slowly through the liquid in one direction, while groups or atoms which have lost electrons and which have thereby become positive pass through the solution, usually at a different rate, in the opposite direction. In the wire the current consists in the flow of electrons; in the electrolyte it consists in the flow of two sets of ions in opposite directions.

My own interest in the chemical side of the electron theory arose from an accident. Some twenty years or so ago I had occasion to perform the old Hofmann experiment with the use of a tube such as I hold in my hand. The tube is filled with chlorine, and when a solution of ammonia is added this chlorine should combine with an equal volume of hydrogen and liberate the nitrogen with which the hydrogen was combined. As ammonia is a compound containing one volume of nitrogen gas combined with three volumes of hydrogen, when water is allowed to enter, as you see it is doing, the tube should be left, at the end of the experiment, one-third full of nitrogen. I happened to use, on the occasion referred to, a dilute solution of ammonia and a smaller amount than usual. At the end of the experiment the tube contained one-sixth of its volume of nitrogen, as you see. I explained the result to the class as best I could, and tucked the matter away in my mind as something that would bear looking into. Several years later, in 1901, I had to find thesis subjects for a number of seniors at the Rose Polytechnic, and remembered the failure in the lecture experiment as a suitable topic. We found that when a solution of ammonia acts on chlorine, nitrogen trichloride (NCl_3) is formed. I explained the action at the time by the following diagram:

DIAGRAM 1.



$\overset{\equiv}{N}$
$\overset{+}{H}$ $\overset{-}{Cl}$ $\overset{+}{Cl}$
$\overset{+}{H}$ $\overset{-}{Cl}$ $\overset{+}{Cl}$ $\overset{\equiv}{N}$
$\overset{+}{H}$ $\overset{-}{Cl}$ $\overset{+}{Cl}$
$\overset{+++}{N}$
$\overset{-}{H}$ $\overset{+}{Cl}$ $\overset{-}{Cl}$ $\overset{+}{H}$
$\overset{-}{H}$ $\overset{+}{Cl}$ $\overset{-}{Cl}$ $\overset{+}{H}$
$\overset{-}{H}$ $\overset{+}{Cl}$ $\overset{-}{Cl}$ $\overset{+}{H}$

Professor Bray has recently pointed out that a ninth-order reaction, such as is implied in this diagram, is, to say the least, highly improbable, but the suggestion that atoms may retain a positive or negative character in reactions which are not usually considered ionic has met with increasing favor. Van't Hoff[1] had made a somewhat similar suggestion about another reaction in 1895, and Professor Stieglitz published a note, shortly after the appearance of the paper by Lyons and myself, saying that he had presented the same idea some time before at the University of Chicago. Neither of us, at the time, thought of any connection between these facts and the electron theory. Three years later Professor Abegg, of Breslau, published a remarkable paper in which he developed the idea of the electrical polarity of the atoms in considerable detail, and proposed his theory of normal valences and of contra valences, the sum of the two kinds of valences for any given atom being eight. Thus a nitrogen atom may develop toward hydrogen three negative, normal valences, or toward oxygen it may assume five, positive, contra valences. In this paper Abegg pointed out for the first time a probable connection between his theory and the theory of electrons.

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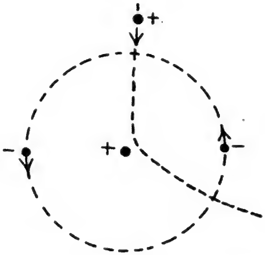
[1] *Z. physik. Chem.*, **16**, 411 (1895).

In the same year, 1904, Prof. J. J. Thomson proposed a hypothesis that atoms consist of electrons within a uniform sphere of positive electricity. He discussed the arrangement of the electrons on this supposition. A single electron would go to the centre of such a sphere. Two electrons, owing to their mutual repulsion, would be in equilibrium at a distance from each other equal to the radius of the sphere. Three electrons would form an equilateral triangle, four a tetrahedron, six an octahedron; but Professor Thomson says that he has been unable to solve the general problem for *n* electrons distributed in a sphere. He gives, however, a rather remarkable solution on the supposition that the electrons are situated in a plane. In that case they will arrange themselves in concentric rings, and for a given number of electrons there is only a single stable arrangement. Further than this, with a given number in the exterior ring, the number which can be placed within is limited by two extremes. The most suggestive case of this kind is that with 20 electrons in the outer ring. The total number of electrons with such an outer ring can never be less than 59 and cannot exceed 67. This might be supposed to correspond to a group of nine elements of the periodic system from helium to neon or from neon to argon. The arrangement with 59 electrons, if it lost one, would be compelled to rearrange to a form having only 19 electrons in the outer ring, but, owing to the positive charge acquired by the loss of the electron, it would immediately acquire another and go back to its original form. Such an element would have a valence of 0 for a positive charge, and Professor Thomson suggests that this would correspond to such an element as helium or neon.

This paper of Professor Thomson's is of special interest because it contains, for the first time, the suggestion that two atoms may be held together by the electrical forces resulting from the transfer of an electron from one atom to another. The hypothesis of an arrangement of electrons within a sphere of positive electricity has been almost entirely abandoned in favor of the belief that atoms contain a positive nucleus which is very small in comparison with what may be called the effective size of the atom, and that electrons rotate around this nucleus at a considerable distance. Rutherford has been one of the leading supporters of this idea, and he bases an argument for it especially on the fact that when positively charged helium atoms are shot through a thin metallic film many of them pass through without deflection, while a few are scattered through a wide angle.

FIG. 10.



The reason for the scattering will be understood from this figure (Fig. 10),[2] which represents an atom with a small positive nucleus around which two electrons are rotating. If a positive helium atom were shot through the orbit of the electrons at a high velocity it would not be deflected appreciably unless it were to pass very close to the central nucleus. In case it came near the nucleus, however, it would be repelled and thrown off at an angle.

Since Prof. J. J. Thomson first suggested that atoms may be held in chemical combination by the electrical forces resulting from the transfer of an electron from one atom to another a number of chemists have used the electron theory in discussing chemical problems. Thus Hentschel pointed out that the three atoms of chlorine in nitrogen trichloride are equivalent to six atoms (three molecules) of free chlorine in oxidizing power. In terms of the electron theory this is easily explained by assuming that in nitrogen trichloride the nitrogen atom has gained three electrons, becoming negative, while each chlorine atom has lost an electron, becoming positive. In order to convert the chlorine of the trichloride to the form in ordinary chlorides each chlorine atom must gain *two* electrons. In free chlorine, on the other hand, one chlorine atom has lost an electron, while the other has gained one, hence the two atoms of free chlorine require only two electrons to convert both atoms to the negative form. Professor Stieglitz pointed out, several years before the electron theory was used in discussing chemical problems, that in reacting with water the negative atom of a molecule of free chlorine combines with the positive hydrogen of the water, while the positive chlorine atom combines with the negative hydroxyl of the water to form hypochlorous acid.

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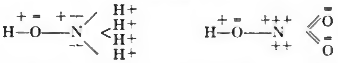
[2] A similar figure has been used by Prof. W. D. Harkins in an address which he has given.

The ordinary valence theory, which takes no account of the electrical forces, gives no satisfactory reason why ammonium hydroxide (H-O-NH_4) should in ionization, give hydroxyl ions, while nitric acid (H-O-NO_2) gives hydrogen ions. When we write the formulas in the light of the electron theory, as shown in this diagram, we see that the negative oxygen of the hydroxyl may be held strongly by the positive nitrogen atom of the nitro group (NO_2), while it is not held so strongly by the nitrogen atom of the ammonium group (NH_4). The nitrogen atom of the latter group has lost four electrons and gained one, if we assume a localization of valence electrons within the atom.

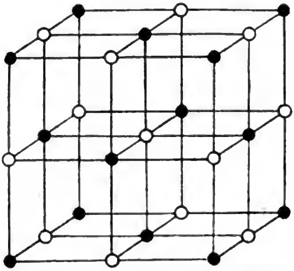
DIAGRAM 2.



I have referred to the X-rays which are generated when the stream of electrons in a Crookes tube impinges on the glass of the bulb. For a long time there were great differences of opinion among physicists as to the real nature of these rays. It is now pretty well established that the X-rays are of essentially the same nature as light-waves, but have an exceedingly short wave-length.

Most of you have learned of the so-called gratings produced by ruling ten thousand or more lines to the inch on a smooth surface. A spectrum is produced by the reflection of light from such a surface, and if the distance between the lines is known it is a simple matter to calculate the wave-length of a bright line of the spectrum found at a particular angle with the surface of the grating. Conversely, if we know the wave-length of the light of the bright line and the angle, it is possible to calculate the distance between the lines of the grating. Laue, the Braggs, Mosely, and others have applied a similar, though not quite identical, principle to the study of X-ray spectra. They have used as gratings the regular rows of molecules in crystals of salt, the diamond, and other substances.

FIG. 11.



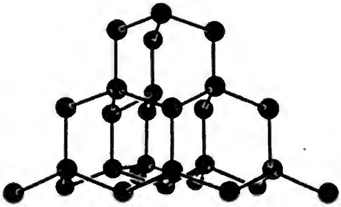
Two results of extreme interest have already come from this study. It has been discovered that each chemical element has a characteristic two-line X-ray spectrum. From these spectra what are known as atomic numbers have been deduced, which fix the position of each element in the periodic system. It is well known that some elements, such as tellurium, have atomic weights which do not fit into the proper place in the periodic system. The atomic numbers of all of the elements so far studied are in the proper order, and we can now say that the atomic number of an element is even more characteristic than its atomic weight.

The X-ray spectra have also been used by the Braggs, especially, to decipher the structure of crystals. This slide (Fig. 11) shows the structure of a crystal of potassium chloride as demonstrated from the results of these experiments, and the next (Fig. 12) gives the very different structure of a diamond.

I think almost nothing has given me such a feeling of the loss which is coming to the world from this dreadful war as the knowledge that Mosely, one of the most brilliant workers in this field, though a young man of only twenty-six, was killed at the Dardanelles.

There must surely be a very close relation between the structure of atoms and the motion of the electrons within them and the spectra of the elements. Some years ago an element called nebulium was discovered by its spectrum in the great nebula of Orion. The element has not been found in the earth. Nicholson, from a study of the spectrum of nebulium, came to the conclusion that the atom of the element contains four electrons rotating about a positive nucleus. At the same time he said that there were two of the spectrum lines of the nebula which he could not account for by this hypothesis. The same day that he presented his paper in England an astronomer, Wolff, gave a paper in Heidelberg in which he showed that the nebula consists of two parts, and the two lines which Nicholson could not explain came from a different part of the nebula from the rest. The two workers were entirely independent and were interested in different problems, so that the coincidence is remarkable, to say the least.

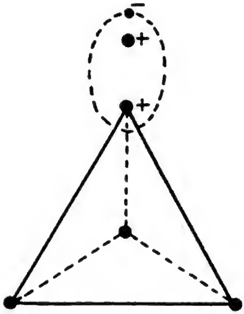
FIG. 12.



The work of physicists during recent years has led to the conclusion that the electrons within the atoms of the elements are in a very rapid rotation about positive nuclei. Chemists, on the other hand, have spoken of the transfer of valence electrons from one atom to another without any reference to the motion of the electrons. It seems possible to unite the two points of view by the following hypothesis.[3]

Let us suppose that two atoms which have an affinity for each other are brought close together. A valence electron which is rotating around a positive nucleus in the first atom may find a positive nucleus in the second atom sufficiently close so that it will include the latter in its orbit, and it may then continue to describe an orbit about the positive nuclei of the two atoms. During that portion of its orbit within the second atom that atom would become, on the whole, negative, while the first atom would be positive. During the other part of its orbit each atom would be electrically neutral, and the atoms might fall apart. When we remember, however, the tremendous velocity of the electrons and the relatively sluggish motions of the atoms, it seems evident that the motion of an electron in such an orbit might hold two atoms together. In ionization the electron would, of course, revolve about the nucleus of the negative atom, leaving the other atom positive. It seems impossible to explain ionization otherwise than on the supposition of the complete transfer of the electron. This complete transfer in ionization is one of the strongest arguments against the magneton theory as the only explanation of chemical combination.

FIG. 13.



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[3] This has now been published in the *Proceedings of the National Academy of Sciences* and in the *Journal of the American Chemical Society*.

An interesting feature of the hypothesis proposed is that it may be used to account for that localization of affinities in particular parts of atoms which is indicated by many of the properties of organic compounds. Thus if we suppose that there are four (or eight) positive nuclei in a carbon atom, around which valence electrons may rotate, an atom of hydrogen may be held to the neighborhood of one of these nuclei as indicated in the figure (Fig. 13).

A few years ago we were accustomed to think of atoms as "manufactured articles," indivisible and unchangeable. The phenomena of radio-activity and the electron theory have demonstrated that atoms are extremely complex entities which may disintegrate into simpler parts. The conclusion is almost irresistible that they may also be formed from simpler parts. The atoms are also tremendous storehouses of energy for which we have not yet found the key. During the last sixty years chemists have deciphered the structure of thousands of compounds of carbon. A hundred years ago this knowledge would have seemed an impossible dream. To-day it is a practical reality, lying at the very foundation of our manufacture of dyes and explosives. Our knowledge of the structure of atoms is still a dream with very shadowy outlines, but I think we may be confident that a not very distant future will see this dream translated into definite details.

I think we may be quite certain that the electron theory is with us to stay, although the theory has found many changes and a very rapid development during its short life, and I cannot do better than to close with the words of Professor Thomson:

"The theory is not an ultimate one; its object is physical rather than metaphysical. From the point of view of the physicist, a theory of matter is a policy rather than a creed. Its object is to connect or coördinate apparently diverse phenomena, and, above all, to suggest, stimulate, and direct experiment. It ought to furnish a compass which, if followed, will lead the explorer further and further into unexplored regions. Whether these regions will be barren or fertile, experience alone will decide; but at any rate, one who is guided in this way will travel onward in a definite direction and will not wander aimlessly to and fro."

A NEW PRINCIPLE IN THE FLOW OF HEAT.*

BY

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WHEN in the usual combustion process the high-temperature flame impinges on a surface which is maintained at a much lower temperature, as for instance in the boiling of water in steam boilers, in cooking utensils on gas stoves, etc., the sudden chilling of the hot gases causes a very thin film of extremely high thermal resistance to form over the flame side of this surface; all the heat which flows usefully from the flame to the water must pass through this very high resistance, which means that the rate of transference of this useful heat is greatly reduced thereby, and that the usual method of boiling water is therefore a very imperfect one.

The existence of this film is shown in the well-known experiment of boiling water in a cup of paper; also by the fact that a piece of ordinary paper, like a postage stamp, pasted on the fire side of a vessel in which water is boiled, will not be charred, though when several are thus pasted over each other the outer ones will become charred. The latter shows that the thickness of this film seems to be of the order of magnitude of about 0.005 inch, hence it is extremely thin. If the flame temperature is taken as about 1350° C., and that of the water is 100°, the drop of temperature through this film will be about 1250° C., showing an extremely high thermal resistivity.

Based on the heat flow through the bottom of an ordinary tin cup while water is boiling in it, the resistivity of this film figures out to be of the order of magnitude of about 79,000 in gramme-calorie-cm.-cube units, which means that a difference of temperature of about 79,000° C. would have to be maintained between the two opposite faces of a centimetre cube of such a film to cause one gramme-calorie of heat to flow through it per second. The resistivity of copper in terms of this same unit is only about 1.26, and that of felt is about 8400.

The resistivity of this film is so extremely high as compared with that of the best thermal insulators, that it is a question whether it is really a true resistance; possibly there exists what might be called a counter thermo-motive force analogous to a counter electro-motive force, which latter may sometimes for convenience be stated in terms of its equivalent in electrical resistance; or possibly the law of the transferrence of the momenta of moving masses may apply to the oscillations of the molecules which constitute thermal energy, in which transferrence it is the momenta and not the energies which are transferred equally; and the density of the cooler gases (the mass per cubic centimetre) is greater than that of the hotter ones; or a relatively very cold surface may have a tendency to reflect rather than transmit some of the heat waves. But, however the production or the physical nature of this film may be explained, the facts are that it exists and that it very greatly obstructs the flow of heat in steam boilers, water heaters, cooking utensils, etc. Until more is known about its physical nature it may in practice be treated as though it were a thermal resistance, as it acts like one.

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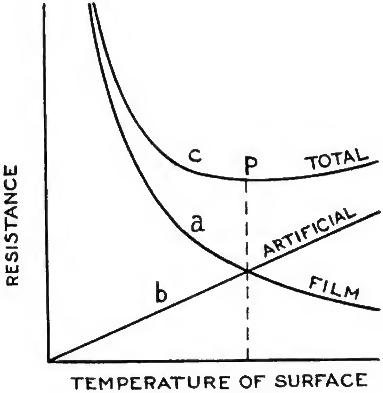
* Communicated by the Author.

A study of the properties of this film, by the writer, showed that its resistance diminishes greatly as the difference of temperature between its two faces is decreased. The temperature of the flame and of the water being fixed, the only way to accomplish this is to greatly increase the temperature of the fire side of the vessel. This can best be done in practice by inserting between the hot and the cold surfaces of the vessel an artificial thermal resistance of such magnitude that the current of heat flowing through it will maintain the hot side at a high temperature. As the difference of temperature between the two ends of a thermal resistance is a function of both the resistance and the flow of heat (like in the electrical analogy), and as the greatest possible flow of heat is what is desired, it follows that this artificial resistance should be made of the best possible heat conductor, so that its resistance may be made as low as possible; it should therefore be made of metal rather than of insulating materials.

The thermal relations are shown roughly in Fig. 1. The ordinates represent the thermal resistances in the path of the heat flow; the abscissæ the temperatures of the flame side of the vessel. The rapidly falling curve *a* then shows approximately how the resistance of this film (or its equivalent expressed in terms of thermal resistance) falls as the temperature of that surface rises. The rising curve *b* shows approximately the thermal resistances which must be inserted to bring that heat-absorbing surface to those temperatures. And curve *c* is the total resistance—that is, the sum of the two others; it is this that governs the flow of heat from flame to water, and it will be seen to have a minimum point *P* beyond which it is no longer advantageous to increase the artificial resistance. Hence by increasing this resistance the flow of heat increases greatly up to a maximum point and then diminishes again. These curves are based on experimental results and not on theoretical deductions, and they are only approximate, as many other factors enter also.

FIG 1



Approximate thermal relations.

Curve *a* may be represented by

$$xy = k,$$

which is only crudely approximate; the data for it are not yet accurately known.

Curve *b* may be represented similarly by

$$y = nx,$$

which also is only crudely approximate, as it curves downward.

The value of x for the point of intersection, therefore, is

$$x = \sqrt{k/n}.$$

The equation of curve c, of which the ordinates are the sum of the other two, then will be

$$Y = k/X + nX,$$

Placing the first differential coefficient equal to zero, gives

$$X = \sqrt{k/n},$$

This is the same as the value of x for the point of intersection, which shows that a minimum point exists above the point of intersection, at which, therefore, the two resistances are equal.

The flow of heat through the artificial resistance and through the film being necessarily equal, it follows, from the above analysis, that in this method of heating the greatest heat flow is obtained when the drop of temperature in the artificial resistance is made approximately equal to that in the film; this means that the temperature of the surface at which the heat enters the walls of the vessel should be about midway between the temperatures of the flame and the water, hence about 725° C. (about 1365° F.), which is a dull red heat. The more this drop of temperature in the artificial resistance is due to the flow of heat and the less it is due to actual resistance, the better. As copper is one of the best heat conductors, the maximum in practice would be that obtained when the artificial resistance is made of copper.

The limit to the rate of flow of heat would be reached when it is so rapid that the spheroidal state starts to take place; that is, when the water side of the surface is no longer kept wetted by the water. Although the writer has been able to increase the heat flow about 27-fold by this method, there were no indications that the spheroidal state had been closely approached, hence there is no probability of reaching it, and if there is, it could be easily avoided by attaching lugs to the water side of the vessel.

Unlike in the analogous case of electrical energy, there is no loss of heat energy or efficiency in overcoming these two thermal resistances; all the calories of heat which enter the hot side issue again from the cold side (assuming perfect lateral heat insulation). The resistances therefore affect only the *rate* of transmission through a given cross-section. But indirectly the thermal efficiency in this case increases with this rate; there are always some unavoidable losses of heat, and if a given quantity of water is evaporated by the same flame in, say, half the time, these losses will take place during only half the time, hence will be halved. A distinction must therefore be made between the rate and the efficiency; the writer has succeeded in increasing the rate about 27 times, but the thermal efficiency in ordinary steam boilers is from 25 to 75 per cent., possibly even a little higher in some very good boilers, and therefore it could not be increased 27-fold, though the losses might be reduced to one twenty-seventh of what they were, if the time of heating could be reduced that much.

In practice the most convenient way to make these artificial resistances is by attaching metallic lugs to the flame side of the vessel. These must be so proportioned in diameter and length that the heat flow through them will maintain their hot ends at a temperature about half way between that of the water and the flame, which is at about a dull red heat; unless so proportioned they will not act as described and would merely add a little to the heat-receiving surface. Such lugs, when properly proportioned, act as though they pierced thermal openings through that highly-resisting film through which the heat then rushes into the water very rapidly, as is shown by the water boiling with extreme rapidity directly over the tops of those lugs.

When these lugs are made shorter and thicker or longer and thinner than they should be, the flow of heat diminishes, as indicated by the curve *c*. As the same thermal resistance may be obtained with short, thin lugs or with long, thick ones, provided the ratio of the diameters and lengths are the same in both, there is a choice open. Practical considerations, such as the expense, weight, space, etc., will generally decide this. Theoretically their best lengths (when vertical) would be such that the above-described relations hold good also for the sides of the lugs over which the partially cooled gases rise; the temperatures of the rising gases and of the vertical lugs both diminish from the hot end up, hence if they both decrease in the same ratio, the water temperature being considered as zero, there will be the greatest possible absorption of heat by the lateral surfaces of the lugs. This means a certain freedom of flow of the hot gases, hence the spacing should not be too close.

The former theory concerning the use of lugs on the heated surface has been that they increase the heat-absorbing surface. While it is undoubtedly true that by increasing the surface covered by this film its resistance as a whole is reduced somewhat, yet the writer's researches have shown conclusively that the increased flow is by no means a function of this surface, and that the older theory is therefore quite fallacious, which no doubt explains why this frequently proposed method of increasing the rate by increasing the surface has not come into general use; the principle was not the correct one. Increasing the surface without breaking down the film may give a small percentage increase, but by breaking down the film resistance as described an increase of several thousand per cent. was obtained.

Special attention was given to this theory of the surface in the writer's researches and many comparative tests were made; the results bore no relation whatsoever to the surface, but they were all in accord with the principle above described. In one case the surface was made four times as great as in another, yet the results were even worse. In another case the lengths and cross-sections were the same, but the surfaces were greatly different by making one set of lugs round and the other flat, yet the latter gave no better results.

The many-fold increase of flow obtained by properly proportioned lugs refers to the flow through the lugs as compared with the flow through the same area of the vessel as that of the cross-sections of the lugs, and therefore is of interest chiefly in showing the correctness of the principle. In practice this extreme result of 27-fold could not be reached, and probably could not even be very closely approached. The lugs in this case were rather far apart; when closer together the flow in each lug becomes less, but the area covered by them then becomes so much greater that the flow per square inch of total surface of the vessel is greater.

With ordinary tin cups over a quiet Bunsen flame of about the same diameter as the bottoms of the cups, and shielding the sides of the cups from the flame, the same amount of water was evaporated in nearly one-quarter of the time with nearly one-quarter of the amount of gas. With the ordinary gas stove, in which it is not possible to get the best relations between flame and lugs, the evaporation was about twice as fast with half the gas. Further refinements in the best application of this principle will probably lead to still better results, especially when the flame also can be made the most appropriate for this purpose. If in steam boiler practice the rate could thereby be merely doubled, it would be of great importance, as it would diminish the size of the boilers by about a half.

The flow through the cup without lugs was about 1.25 gramme-calories per second per square centimetre. Through the lugs themselves as much as 34 gramme-calories were obtained, which is about 27 times as fast. Through the whole bottom, including the space covered by the lugs and that between them, the rate was about 4.35, which is nearly four times that in the cup without lugs, and the best conditions had no doubt not yet been reached. The ordinary boiler practice, three pounds of water evaporated per hour per square foot at and to 212° F., is equivalent to 0.218 gramme-calorie per second per square centimetre; in such boilers the flames and the heating surfaces cannot be as well adapted to each other as in direct heating by gas flames, which explains why this is only about a sixth of the rate obtainable in boiling over gas stoves.

A Lamp Filament for Motion-picture Machines. ANON. (*Electrical World*, vol. 70, No. 13, p. 620, September 29, 1917.)—Because in any faint source of light the rays entering the condensing lenses necessarily form a conical beam, Albert S. Moffat, of Belmont, Mass., proposes, in patent No. 1,222,119, to dispose an incandescent-lamp filament in a hollow pyramidal form, the base of which is similar in contour to the picture space to be illuminated, and to have the filament composed of a long helix wound in a spiral about such a pyramid.

To this end the filament will not only intensify the light emitted therefrom, but will concentrate it upon the rectangular space occupied by a motion-picture section. In the usual form of light the rays issue in the shape of a cone whose base is circular and consequently must lap over the rectangular picture space to an extent fully equal in area to that of the space utilized. By having the filament in a helix a maximum of light-rays is obtained in the minimum of space. By having the helix wound as a hollow pyramid the emitted rays are concentrated upon a smaller space than would be the case were the helix coiled in a single plane parallel with the plane of the picture. This is because the rays from the inner turns can pass the outer turns only by issuing in a straight line within the outer turns, and so on to the film, conforming in contour to the rectangular shape of the picture.

Historical Note on the High-tension Magneto. A. P. YOUNG. (*Aerial Age Weekly*, vol. 6, No. 2, p. 64, September 24, 1917.)—The degree of success achieved in the evolution of the combustion motor has at all stages been primarily dependent upon the efficiency of the ignition system used, and it is no exaggeration to say that the rapid strides which have been made during recent years in the construction of the petrol motor have mainly resulted from the very satisfactory high-tension ignition system that has been available. All electrical systems of ignition are direct descendants of Faraday's great discovery of electro-magnetic induction, made during the autumn of 1831, when for the first time in the world's history he succeeded in producing a spark by magnetic means.

The first system of electric ignition ever used was devised by Lenoir in 1860. He utilized the high-tension spark of a Ruhmkorff coil for ignition purposes, employing a high-tension distributer for connecting the secondary winding first to one plug, then to the other. It is worth noting that the modern battery system of ignition now used most extensively in the United States is strikingly similar to the old Lenoir system, even to the detail of introducing an extremely small air-gap between the rotating metal brush and the distributer segment, a method of distribution that is now being followed on magnetos. Lenoir was also the inventor of the spark plug, and the type of plug which he designed for use in conjunction with his ignition scheme of 1860 had all the features of the modern spark plug.

Marcus appears to have been the first man to construct a magneto for ignition purposes. His was a low-tension machine having the new familiar form of H-armature, the current induced in the winding being broken at predetermined times in the cylinder by cams and levers. In 1898 Simms and Bosch developed a low-tension magneto, using a fixed H-armature and rotating segments for producing the necessary flux changes in the armature core. This is of special interest because subsequently, by the addition of a secondary winding on the same armature core, a high-tension magneto was evolved.

The Bosch Company of Stuttgart, Germany, must receive the credit for having thoroughly established the fact that a high-tension magneto can be manufactured on a commercial basis to give reliable and efficient ignition in practice. Although this important industry was developed in Germany, the modern high-tension magneto was first conceived in France by M. Boudeville, who unfortunately omitted to include a condenser in his scheme for eliminating sparking at the contact points. A condenser is a vital part of every magneto; without it the machine would be quite impracticable. It is surprising that Boudeville should have overlooked this feature, because here again the idea of using a condenser for such a purpose is of French origin, Fizeau, in 1853, being the first to suggest connecting a condenser in parallel with the contacts on a Ruhmkorff coil to prevent excessive sparking.

PHYSICS OF THE AIR.*

BY

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CHAPTER X.

ATMOSPHERIC CIRCULATION (*continued*).

Winds Due to Widespread Heating and Cooling (continued).

EXTRA-TROPICAL CYCLONES.

General Remarks.—The strong winds and heavy precipitations of middle latitudes are associated with the occurrence of low barometric pressure, while gentle winds and clear skies as commonly are associated with the occurrence of high barometric pressure. Hence the cyclone, or that system of winds that accompanies and surrounds any considerable region of minimum pressure, and the anticyclone, or that system of winds that belongs to and encircles a region of maximum pressure, deserve and have received a vast amount of observation and study. Nevertheless, in many respects—in their origin, in their temperature distributions, and in the laws of their movements—cyclones and anticyclones still remain in great measure the meteorological mysteries they have always been.

Although the cyclones and anticyclones of extra-tropical regions are as closely associated and as fully the complements of each other as are hills and hollows, it nevertheless will be convenient to consider them independently. It will also be convenient first to summarize the facts of observations, and then to string these facts together on the thread of a provisional theory.

Size.—The area covered by an extra-tropical cyclone, the largest of all distinctive storms, nearly always amounts to millions of square kilometres. In North America the average diameter of these storms is estimated to be, roughly, 2500 kilometres (1553 miles), which probably is not greatly different from their average diameter on other continents. Over the North Atlantic their diameters are still larger, while the greatest of all in size is the semipermanent or winter Aleutian "low," which appears usually to be much larger than the travelling cyclones of the Atlantic or even the great semipermanent Icelandic " low."

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* Continued from page 836, vol. 184, December, 1917.

Direction of Movement of the Cyclonic Centre.—The direction the centre of a cyclone travels, wherever it may be located, is substantially the same as that of the higher clouds or of the atmosphere at 6 to 10 kilometres above sea level. In general, therefore, the cyclones of middle latitudes travel from west to east, with (in the northern hemisphere) a southerly dip over continents and a northerly deflection over oceans. Cyclones, for instance, that develop between latitudes 30° and 45°, in the western United States, usually turn northeast before reaching the Mississippi River. Farther west they may move east, or even somewhat southeast.

Locus of Maximum Cyclonic Frequency, or Chief Paths of Cyclonic Storms.—Probably no part of the earth's surface more than 3 or 4 degrees from the equator is wholly free from cyclonic storms, but the frequency of their occurrence varies greatly with respect to both time and place. Beginning with the West Pacific: During summer and fall many cyclonic storms come from the general region of the Philippines and move northeast across or on either side of Japan. Winter and spring cyclones enter on this same general course at latitudes 30 degrees to 40 degrees; some, presumably, being of oceanic origin, while others obviously either develop within or cross over China. In any case, the general track of these storms is along the Japanese and Kurile Islands, and thence east over the Bering Sea. The main path is then southeast across the Gulf of Alaska, with the storms, including off-shoots from the Aleutian " low," crossing onto the continent anywhere between latitudes 40 degrees and 60 degrees, but apparently most frequently in the general neighborhood of Vancouver Island. These Pacific storms usually cross the continent nearly from west to east, dipping slightly south over the Great Lakes, and finally leave it by way of Newfoundland. A smaller number of storms from the North Pacific dip far south, somewhat like the Mediterranean branch mentioned below, to about latitudes 35 degrees to 40 degrees, but usually recurve west of the Mississippi and join the main course as they reach the Atlantic. Those that originate in or cross over the central and southern portions of the United States, as also those that come from the Gulf of Mexico, move northeast and gradually merge their paths with that of the Pacific storms anywhere from the Great Lakes to the Newfoundland Banks. Other cyclones coming up from the Florida and West Indies regions follow the coast, not far off shore, and also merge their paths with that of the others in the neighborhood of Newfoundland. Half-way or more across the Atlantic the path of maximum storm frequently breaks up into at least three distinct routes. The main route turns far north, usually by way of the Norwegian Sea, then southeast, entering Russia in the neighborhood of the White Sea, and passing on toward Central Asia. A second route turns southeast and crosses Europe generally along the northern side of the Mediterranean, and then turns north either across Austria toward northwest Russia or by way of the Black Sea toward Central Asia. A third and least frequented route, commonly running just south of Ireland, appears to cross both the North and the Baltic Sea, and then, like the others, to move on toward Siberia and central Asia. The cyclonic storms of central and northern Asia do not appear to be very numerous. Nevertheless, their track of maximum frequency seems to turn south, as does the similar track over North America, as far as Lake Baikal, thence probably to the Sea of Okhotsk and across or to the south of Kamchatka to the main storm path north of the Aleutians, as already explained.

In the southern hemisphere the path of maximum storm frequency appears closely to follow the 60-degree parallel of latitude. Presumably it dips poleward at both the Ross and the Weddell Sea, as each of these is a region of semipermanent low pressure.

It must be remembered, in this connection, however, that in both the southern hemisphere and the northern cyclonic storms occur almost everywhere, and therefore that the routes above described are only paths of maximum cyclonic frequency and not of exclusive travel.

Velocity of Travel.—The velocity with which the centre of a cyclonic storm moves along its path varies greatly. It depends upon the season, being fastest in winter and slowest in summer; upon location, being faster in America than in Europe, for instance; and, finally, upon the individual storm.

The following table gives average velocities for different parts of the northern hemisphere. Those pertaining to the United States were computed from a table of average 24-hour movements as determined by Bowie and Weightman[48] from 16,239 observations, covering the years 1892–1912, inclusive. The others are from Hann's "Lehrbuch der Meteorologie," 3d edition, p. 518.

Average Velocity of Cyclones in Metres per Second.

(For the United States the velocity is also given in miles per hour.)

	United States	Japan	Russia	North Atlantic	West Europe	Bering Sea.
Winter......	(29.9) 13.4	12.4	10.8	8.2	8.0	8.5
Spring......	(23.7) 10.6	11.1	9.2	8.3	7.2	8.5
Summer.....	(20.7) 9.3	7.8	8.0	7.4	6.6	10.3
Fall.........	(24.5) 11.0	10.6	9.6	8.3	8.2	9.3
Year........	(24.7) 11.1	10.5	9.4	8.05	7.5	9.1

Frequency.—The frequency of the occurrence of cyclonic storms varies not only from place to place, as already explained, but also at any given place, or even over an extensive area—probably an entire hemisphere—according to season. Tropical cyclones, it will be recalled, are far more frequent during summer and early fall than during winter. Mid-latitude cyclones, on the other hand, have exactly the opposite relation of frequency to season, being, in general, most numerous in winter and least numerous in summer. Exceptions to this rule apply to the paths of tropical cyclones next after the recurvature, provided we regard such storms as having them become extra-tropical. Perhaps exceptions also apply to certain regions on the poleward sides of the main cyclonic routes, since these are farthest north in summer and farthest south in winter. This, however, is not certain. A statistical investigation might show that even the greatest increase due to latitude shift is more than compensated by the general seasonal decrease in frequency.

When all storms are counted that appear in the United States or Southern Canada, whether short or long lived, weak or intense, in appears[49] that the frequency of summer (June, July, and August) "lows" is to that of winter (December, January, and February) "lows" approximately as 5 to 8. On the other hand, if only long-lived cyclones are considered, it appears[50] that in the

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[48] *Monthly Weather Review*, Supplement No. 1, p. 8, 1914.

[49] Bowie and Weightman, *Monthly Weather Review*, Supplement No. 1, p. 7, 1914.

[50] U. S. Weather Bureau Bulletin A, p. 6, 1893.

United States the frequencies of summer to winter storms are about as only 2 to 9, and those of Europe as 3 to 10.

In either case, then—that is, whether only the longer lived and more intense "lows" are counted, or whether all, of whatever magnitude and duration, are included—it seems that cyclonic storms are most frequent during winter and least frequent during summer. Further, the extra-tropical storms of winter are not only more numerous than those of summer, but also, in general, longer lived, more intense, and faster moving.

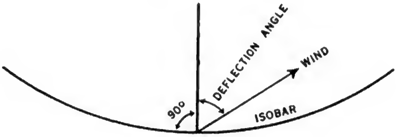
Direction of Winds.—From the directions of winds in and about a region of low barometric pressure, as given on synoptic charts, it is often, perhaps usually, inferred that cyclonic winds circulate spirally inward and upward and then outward and upward, counter-clockwise in the northern hemisphere, clockwise in the southern, around a storm axis. This indeed is, in general, the course of the winds in tropical cyclones, especially in those that are violent and of small diameter, as the eye of the storm and directions of cloud movements clearly indicate, but it does not apply to extra-tropical cyclones, except, perhaps, to the occasional ones of great violence and small diameter. Extra-tropical cyclones rarely have clear centres, as they would if the circulation about them was closed or along spiral paths of repeated turns. Neither, in general, is a closed circulation indicated by the movements of the clouds. Again, it often happens that the velocity of the forward moving wind of a cyclone is less than that of the storm itself, so that instead of flowing around the storm centre it necessarily is left behind.

Synoptic weather charts, therefore, show instantaneous wind directions, but not wind-paths. This is because the storm condition itself is moving forward—moving, indeed, with a velocity nearly always comparable to, and at times even faster than, that of the lower winds themselves.

The main body of the storm winds, those below an elevation of 5 or 6 kilometres, except everywhere near the surface, and also generally about the poleward side above 2 to 3 kilometres elevation, blow, in the cyclonic sense, roughly parallel to the surface isobars. This does not mean that the path of any given particle of air is around and around the centre of low pressure, because, as above explained, this centre itself and its system of isobars are both in rapid transit. Near the surface the velocity is so slowed down that the deflection forces no longer balance the horizontal pressure, and therefore the winds of this level are directed inward at a considerable angle across the isobars. Through the poleward half of the storm area the horizontal temperature gradient is nearly always opposite in general direction to the horizontal pressure gradient at the surface. Therefore, with increase of elevation in this section the pressure gradient usually weakens from the start and later reverses at the height of only a few kilometres; while the winds first increase (where the surface drag rapidly decreases) to a maximum, then decrease, and later more or less reverse in direction.

Deflection Angle.—The angle between the surface wind direction at any place within a cyclonic storm and the normal to the corresponding isobar, the "deflection" angle (Fig. 47), is greatest, or the surface winds most nearly parallel to the isobars, *a*, when the winds are swiftest and thus develop the strongest deflective forces—therefore greatest to the south and east of the storm centre and least to the north and west, *b* when the velocity of the storm as a whole is least, *c*, in the summer time, because during this season the storm movement is less than during other seasons, *d*, over water where it is roughly 80 degrees, because the surface drag is less here than over land where the "deflection" angle averages only 40 degrees to 50 degrees.

FIG. 47.



Deflection angle.

It is important to note also that usually the deflection angle does not greatly change with distance from the centre. This follows from the fact that the horizontal pressure, the wind velocity, and the consequent surface friction and percentage loss of gradient velocity all are roughly constant in any given direction from the centre, so long as only points distinctly within the storm area are considered.

With increase of elevation and consequent decrease of surface drag the deflection angle over land gets larger by 25 or 30 degrees in the first kilometre. Beyond this elevation it still gains, but relatively very slowly. At an elevation of several kilometres the velocity of the air is decidedly greater than that of the storm, and therefore air that may have risen to this level is carried forward. Hence the main outflow of the extra-tropical cyclone is toward the east.

Wind Velocity.—As just stated, the pressure gradient and wind velocity are roughly constant along any given radius from the storm centre. This is because at middle and higher latitudes the deflective force is essentially geostrophic (due to the rotation of the earth) and to only a small extent cyclostrophic (due to circular motion). The winds, however, often are different in different portions of the storm area, and commonly strongest in its southern and eastern quadrants, where the isobars are most

Cyclonic Wind Velocity in Metres per Second and (Miles per Hour).

Altitude		Surface 122 m.	500 m.	1000 m.	1500 m.	2000 m.	2500 m.	3000 m.	3500 m.	4000 m.
South quadrant	Winter	6.16 (13.8)	14.75 (33.0)	15.09 (33.8)	15.32 (34.2)	15.79 (35.3)	16.85 (37.7)	18.28 (40.9)	19.25 (43.1)	20.30 (45.4)
	Summer	5.42 (12.1)	9.64 (21.6)	10.69 (23.9)	11.31 (25.3)	12.22 (27.3)	12.91 (28.9)	14.08 (31.5)	15.69 (35.1)	17.21 (38.5)
	Year	5.84 (13.1)	12.24 (27.4)	12.93 (29.0)	13.38 (30.0)	14.07 (31.4)	14.94 (33.4)	16.24 (36.3)	17.53 (39.2)	18.81 (42.1)
West quadrant	Winter	6.70 (15.0)	13.47 (30.1)	13.39 (30.0)	13.93 (31.2)	14.75 (33.0)	16.18 (36.2)	17.31 (38.7)	17.31 (38.7)	....
	Summer	5.66 (12.7)	9.45 (21.2)	9.89 (22.1)	9.91 (22.1)	10.17 (22.7)	10.65 (23.8)	11.40 (25.5)	12.07 (27.0)	12.62 (28.2)
	Year	6.06 (13.5)	11.34 (25.4)	11.52 (25.7)	11.80 (26.4)	12.34 (27.6)	13.29 (29.8)	14.23 (31.9)	14.56 (32.6)	....
North quadrant	Winter	4.72 (10.5)	8.85 (19.8)	8.95 (20.0)	9.00 (20.1)	9.09 (20.4)	9.07 (20.3)	9.32 (20.8)	8.52 (19.0)	8.02 (17.9)
	Summer	4.84 (10.8)	7.85 (17.6)	8.37 (18.7)	8.45 (18.9)	8.81 (19.7)	9.11 (20.4)	10.26 (22.9)	10.63 (23.8)	10.63 (23.8)
	Year	4.79 (10.7)	8.36 (18.7)	8.66 (19.4)	8.72 (19.5)	8.94 (20.0)	9.08 (20.3)	9.78 (21.9)	9.57 (21.4)	9.32 (20.8)
East quadrant	Winter	4.50 (10.1)	10.45 (23.4)	10.02 (22.4)	10.43 (23.4)	10.58 (23.7)	11.64 (26.0)	12.11 (27.1)	13.37 (29.9)	14.59 (32.7)
	Summer	4.11 (9.2)	8.22 (18.4)	8.64 (19.4)	8.77 (19.6)	8.98 (20.1)	9.50 (21.3)	9.50 (21.3)	9.81 (21.9)	11.86 (26.5)
	Year	4.34 (9.7)	9.37 (20.9)	9.37 (20.9)	9.64 (21.6)	9.82 (21.9)	10.61 (23.7)	10.84 (24.3)	11.62 (26.0)	13.25 (29.7)

crowded and the direction of the winds roughly that of the storm movement.

The actual average velocity of the wind in the different quadrants of a cyclone and at different elevations is given in the preceding table by Peppler,[51] based on a large number of measurements made during 1903–1908, at Lindenburg; latitude 52° 10′ N.; longitude, 14° 15′ E. Probably other mid-latitude regions have approximately the same average cyclonic wind velocities. This, however, is not certain, nor are there available sufficient data for determining the question.

Convection.—The vertical movements of the air, whether up or down, in an extra-tropical cyclone, or between such a cyclone and a neighboring anticyclone, are not known with much detail and accuracy. However, since the cyclone moves eastward with the air currents directed inward across the isobars, it is obvious that ordinarily the chief air convergence, due in part to increase of latitude, and hence the principal vertical convection, must be on the front or east side. Temperature also usually helps to locate the chief upflow in this quadrant, since its winds necessarily are from lower latitudes, and, therefore, relatively warm.

This localization of the uprising air explains why, other things being equal, most of the precipitation due to cyclonic storms occurs to the east and southeast (northeast in the southern hemisphere) of their centres.

Other things, however, are not always equal. Thus an extensive plain rising gradually to great elevations may slope in such direction that the mechanical or forced convection over it on any side of a cyclonic centre may approach, or even exceed, the thermal convection to the east. The Great Plains east of the Rocky Mountains illustrate this point. Here precipitation in the case of "stagnant" or slow-moving lows usually is most pronounced to the north of the centre where the winds are persistently up the slope. This is an extreme case, but it suffices to show that a rule relating to shifting winds and clear or foul weather that applies well in one place may not apply at all in another. Similarly, on the Pacific coast of North America, for instance, where the ocean is to the immediate west, the heaviest rains are to the south and west of the cyclonic centre.

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[51] *Beiträge zur Physik der freien Atmosphäre*, 4, p. 95, 1911.

Classification.—Cyclones occur in extra-tropical regions with such great frequency that several such storms are nearly always present in each hemisphere. Naturally they have been much studied and therefore variously classified, especially according: to duration, as semipermanent and migratory; to season of occurrence, as summer and winter; to zone of origin, as tropical and extra-tropical; and to the place from which first reported as, for instance (referring to only those within or near the United States), Alberta, North Pacific, South Pacific, Northern Rocky Mountain, Colorado, Texas, East Gulf, South Atlantic, and Central.

All these classifications are useful, but not adapted to the present purpose, which is to group the cyclones, as far as practicable, according to their more important causes. Perhaps this end will be fairly well served by dividing them into *thermal* (identical with semipermanent), *insolational,* and *mechanical.*

Thermal (Identical with Semipermanent).—The name semipermanent cyclone—for which the alternate name, thermal cyclone, is here proposed for reasons that will appear below—or semipermanent "low," has been given to that system of winds of any region over which the barometric pressure habitually or seasonally averages lower than for the surrounding regions. The term generally is used as though it applied to but one and the same cyclone, however it might wander or even for a time wholly disappear. Thus, one always says *the* Icelandic "low," not *an* Icelandic "low." Similarly, *the* Aleutian "low," not *an* Aleutian "low." But, as stated, this applies only to average conditions. In reality there is no one permanent Icelandic "low," for instance, that retains its identity wherever it may be, but only a series of sluggish or temporarily fixed lows, all of which originate over, or, on invading, become intensified over, practically the same restricted region.

There are several semipermanent cyclones in various parts of the world. The nearest to continuously active of these, at least in the northern hemisphere, and at all times apparently one of the most productive of migrating cyclones, lies southeast of Greenland and southwest of Iceland. Another such region, active during winters only and known as the Aleutian "low," lies along and to the south and southeast of the Aleutians, extending into and including the Gulf of Alaska. The Norwegian Sea and, possibly, the Sea of Okhotsk are other such high-latitude regions. The Gulf of Lyon is a low-pressure haunt during winter, as is also the Black Sea, and the Caspian Sea, as its monsoon winds definitely show. The Gulf of Mexico, over which occasional winter cyclones appear to generate, may likewise be added to the above list.

In the southern hemisphere the regions of most persistent lows are the Ross Sea and its counterpart, the Weddell Sea, on the other side of the continent.

All the above regions have surfaces warmer than those that at least partially surround them. The circulation induced by such temperature distribution is converted into a system of cyclonic winds by the deflective force due to the earth's rotation. The warm waters off the coast of Greenland and Iceland, for instance, necessarily maintain the atmosphere above at higher temperatures, level for level, than that of the neighboring ice-caps. Hence a practically continuous overflow of air from the one place, with compensating drainage and inflow from the other, is enforced by the existing and perpetually maintained distribution of unequal surface temperatures. These temperature contrasts are most pronounced, and the resulting Icelandic " low " most intense, during winter; but it prevails through summer also, for the simple reason that the necessary temperature gradients, though weakened during this season, are neither obliterated nor reversed—the water remains always warm in comparison with the ice-caps of both Greenland and Iceland, which persist from season to season and from year to year.

The Aleutian " low," on the other hand, is merely seasonal: it prevails only while the adjacent Alaskan and Siberian regions are snow-covered and relatively cold. When this snow is gone the temperature gradients are even reversed, and the off-shore drainage of winter is replaced by the on-shore winds of summer. Similar considerations and explanations obviously apply to all the other regions frequented by semipermanent cyclones.

Insolational.—Since warm gulfs and seas flanked by relatively cold land areas induce, as explained above, more or less permanent cyclones, it follows that warm peninsulas flanked by relatively cold water should also be generators of cyclonic wind systems. Similarly, any area of sufficient size that becomes heated through insolation to temperatures above those of the adjacent regions should likewise induce or tend to induce a circulation of the cyclonic type. The Spanish peninsula shows, during summer, the phenomenon in question. It also occurs over the Alaskan peninsula onto which summer winds blow from the Gulf of Alaska, from Bering Sea and from the Arctic Ocean, obviously producing, through rotational deflection, a distinct cyclonic circulation. Similarly, the Great Plains often show daylight or insolational lows from which occasional cyclonic storms appear to originate.

Of course, entire continents show low average pressure during summer and high during winter, while in each case the opposite condition applies to the oceans. Such conditions, however, are not especially productive of storms, because the areas involved are hyper-cyclonic in size—so large, in fact, that they only modify the general or planetary circulation without producing local disturbances within it. Neither do temperature contrasts between areas that are very small in comparison with that of the average cyclone produce extensive precipitation, but mere local disturbances quickly smoothed out by the general circulation, or, at most, only thunder showers. In short, for the development of cyclones by temperature contrasts the warm area must be neither too large nor too small, neither continental in extent nor in size a mere island or bay.

Mechanical.—The mechanical " low " is divisible into two classes: (1) Permanent—in reality not a cyclone at all in the ordinary sense of a low centre with encircling isobars—and (2) migratory—the characteristic cyclone of middle latitudes. In the first class, certainly, and presumably in the second also, the low pressure is rather the *result* than the *cause* of the associated winds. Indeed, in the case of any steady wind, except those near the surface or close to the equator, its sustaining force (force in its direction) is small in comparison with the deflective force at right angles to its path due to the rotation of the earth.

Mechanical (Permanent).—There are two well-developed, permanent lows of this type (mechanical) and also an imperfectly developed third. These are (*a*) The equatorial low, which roughly follows the equator through its entire course, due partly to the relatively high temperature of this belt (to that extent an insolational " low ") and partly to the right and left deflective forces of the westward winds of the northern and southern hemispheres, respectively. (*b*) The Antarctic trough, encircling Antarctica generally between 60 degrees and 70 degrees S. and having an annual average pressure of about 740 mm., mechanically sustained jointly by the northward pressure of the swift west winds over the oceans and the southward pressure of the east to west component of the vigorous southeast air drainage or fallwinds of Antarctica. (*c*) The Arctic trough, irregular in outline and intensity and apparently only fragmentary.

Mechanical (*Migratory*).—The great majority of extra-tropical cyclonic storms are migratory, and apparently originate either by breaking off from or in some manner being induced by the semipermanent and insolation lows, or, occasionally, by somehow forming at almost any other place, especially along the more frequented storm paths. The genesis, development, and detailed structure of these storms are by no means well understood, and therefore the following tentative hypothesis in respect to their origin and maintenance is offered chiefly as a convenient mnemonic by which the principal known facts concerning them may be remembered.

Tentative Hypothesis of the Origin and Maintenance of Migratory Cyclones.—It will be recalled that the prevailing wind movement of middle latitudes is from west to east, and that to a first crude approximation (more nearly attained in the southern hemisphere than in the northern) parallels of latitude are followed with such velocity that the poleward pressure gradient is just balanced by the rotational deflection. Obviously, however, numerous surface inequalities, irregularities of temperature distribution, cloudiness, precipitation, and the like, prevent this gradient from being constant along any parallel of latitude or even remaining constant at any given place. Hence the prevailing winds themselves, being primarily under the control of this gradient, correspondingly vary in direction and velocity. Also, because of surface friction, there is much air leakage across the dynamical partition of swiftest winds (usually along parallels of 40 to 60 degrees) to higher latitudes, and, of course, an equivalent return flow.

Now let a disturbance, due to whatever cause, deflect a considerable and rather deep section of the eastward flowing air toward the adjacent pole. Immediately it flows eastward faster than before, in accordance with the law of the conservation of areas, and thus crowds upon the air in front, unless it in turn has sufficient velocity to keep out of the way, a condition that probably does not usually obtain. Because this air comes from lower latitudes and therefore commonly is relatively warm and its absolute humidity often great, and also because it is flowing to regions where the meridians are crowded closer together, it necessarily rises, and in so doing usually yields abundant precipitation, whose latent heat materially aids to perpetuate the storm—continuously to develop a " low " in the forward quadrant.

Simultaneously as this broad body of air sweeps to higher latitudes an equivalent amount, necessarily to the westward, moves in the opposite direction. Indeed, this return branch may have contained the initial impulse; the results would be the same. Here, also, the law of the conservation of areas applies. The return current necessarily lags and in some measure checks the eastward flow of the air to the rear. In this manner the atmosphere between the two components of the horizontal circulation, the forward speeding up, the rearward lagging, is mechanically more or less expanded (stretched), while that on both sides is compressed. The lower air, especially in front of the storm centre, being retarded by friction and turbulence, flows spirally inward, then upward and out. The " low " thus, or however, formed, constitutes a travelling break in the partition between the mid-latitude and high-latitude circulations. In front of the " low " the primary circulation finds its way to colder regions, while to its rear return currents simultaneously bring equivalent amounts of other air to warmer sections. At any rate, whatever the region of extratropical cyclones, it is obvious that much of the interzonal circulation between middle and high latitudes, perhaps by far the greater part of it, occurs simultaneously on their opposite sides. Between the tropical and extra-tropical regions the chief intercirculation is through the trades and countertrades—to lower latitudes by the former, mainly, and to higher chiefly by the latter.

Since the area covered by a cyclone or anticyclone is very great, averaging, roughly 2×10^7 square kilometres, it would seem, as abundantly supported by cloud movements, that each must directly involve at least the whole depth of the troposphere. On the other hand, the stratosphere, from its different temperature, humidity, and wind velocity, appears to be relatively passive, suffering rather than causing either cyclonic or anticyclonic effects.

According to this conception, the troposphere within a cyclonic area is mechanically expanded and, besides, has a marked upward component. It therefore must be cooled, though in the east quadrant, where the wind is from lower latitudes, the warming on that account may equal or even exceed the expansional cooling. Similarly, in an anticyclone the troposphere is mechanically compressed and also has a downward component, thus producing a temperature increase, except, possibly, on the east or forward side, where this effect may be equalled or exceeded by the transfer of colder air from higher latitudes. Hence, because of opposite directions of convection, upward (cooling) in the cyclone, downward (heating) in the anticyclone; contrary changes in pressure, decrease (cooling) in the cyclonic area, increase (heating) in the anticyclonic; and, presumably, inequality of radiating power due to differences of moisture content—the descending (warming) air of the anticyclone being relatively dry and thus heat preserving—one might expect to find, as observations (referred to later) show, that the troposphere is comparatively cold in cyclones and warm in anticyclones, except, perhaps, near the surface, where convection is less operative.

If, as seems likely, cyclonic and anticyclonic winds involve the troposphere through its whole depth, it follows from Egnell's law, $\rho v = $ a constant, with change of elevation, that the pressure gradient is also a constant, and, finally, that the pressure difference between a high and its neighboring low may be of the same order of magnitude at all levels up to the top of the troposphere.

Further, if the stratosphere is essentially inert in respect to the genesis and progress of surface storms, it clearly must sink to lower levels over cyclonic areas and be raised to higher over anticyclonic, and thereby itself undergo pressure and temperature changes,[52] and also briefly (during the formative stage) manifest cyclonic and anticyclonic wind systems.

Let a stratospheric column be dropped bodily a distance dh, and let the surrounding air come in until equilibrium is again established. At each level there obviously will result a change in pressure directly proportional to the pressure at that level. That is, throughout the column

$$\frac{dp}{p} = K, \text{ a constant.}$$

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[52] Shaw, "Perturbations of the Stratosphere," M. O. 202, p. 47, 1909.

But, as is well known,

$$\frac{dT}{T} = C\frac{dp}{p},$$

in which T is the absolute temperature, and C a constant, 0.2843 for dry air. Hence, since T is constant, roughly, in the stratosphere, dT is also constant, and the upper air remains vertically isothermal, whatever the pressure increase or decrease. An increase of pressure in the stratosphere, such as presumably takes place over cyclones, *increases* its temperature, while a decrease of pressure, such as probably occurs over anticyclones, correspondingly *decreases* its temperature. In each case the pressure effect presumably is slightly enhanced by the coincident change in the intensity of radiation from below.

Suppose the temperature of the stratosphere over a cyclone should differ from that at the same place over the following anticyclone by 10° C., what, according to the above conception, will be the approximate change of boundary level? Let h be this change, and let the temperature of the stratosphere be 220°, absolute: Then since

$$\frac{dp}{p} = \frac{dh}{H},$$

in which H is the height of the homogeneous atmosphere, about 6450 metres at the assumed temperature, it follows that

$$\frac{10}{220} = 0.2843\frac{h}{H}, \text{ roughly,}$$

and

$$h = 1 \text{ kilometre, approximately,}$$

That is, the temperature of the stratosphere will increase or decrease at the rate of approximately 10° C. per kilometre enforced fall or rise, respectively, under the influence of cyclonic and anticyclonic disturbances.

While migratory cyclones of this nature, mechanical or counter-current, may originate almost anywhere outside the tropics, it is evident that some places are far more favorable to their genesis than others. Among such favorable places it is probable that the Gulf of Alaska is one of the most pronounced, at least during winter, since here the relatively warm water gradually creates a " low " that deflects in a northerly direction the air currents to the south and southeast, and to a southerly direction the air currents to the north and northwest. Hence a low formed over this gulf, or farther west along the Aleutian Islands, is likely to become accentuated on its eastern side through the advent of warm air and the onset of heavy precipitation, and therefore be carried away from its moorings, as it were, and set adrift along the great air currents, where, as already stated, it acts as a travelling centre of vigorous interzonal circulation between middle and high latitudes. Of course, the very process that forces the storm away from its place of origin brings in colder air, usually from higher latitudes. But this, in turn, is slowly warmed from the great supply of heat in the water below, and thus all those conditions essential to the breaking off of another storm similar to the previous one are established, and so on indefinitely, or until the season and consequent temperature distributions so change as to prevent such action.

According to this conception, the permanent "low" around which interzonal circulation tends to be active often produces that local disturbance or deflection of the general circulation necessary to the genesis of a mechanical or dynamical cyclone. Further, although the necessary mathematical demonstrations may not be obvious, it appears in a general way that such a cyclone would travel a course and tend to exhibit characteristics as follows:

a. The storm would travel with the general circulation.

This is fully supported by observations.

b. It would tend, in general, to follow the path of maximum winds, this being the course approached by the west-to-east circulation, and therefore to travel along (not down, but at right angles to) the maximum interzonal temperature and pressure slope.

This inference is also supported by observations.

c. It would tend to follow normal annual isotherms.

This, too, is in accord with observations.

d. Because the winds to the east and southeast (northeast in the southern hemisphere) of the front generally are relatively warm and humid, and because they are focused in direction, thus leading to congestion that forces the rear winds to climb over those in front, it follows that, except as modified by topography and proximity to oceans, these would be the quadrants of maximum precipitation, as indeed they commonly are, except along west coasts.

e. The rising and, therefore, rain-producing air should flow off eastward with the general circulation.

The cirrus and other high level clouds that forerun the cyclone amply support this inference.

f. The mechanical cyclone should usually be accompanied by a correlative anticyclone to its rear.

There is much observational evidence in support also of this conclusion.

g. The average latitude of cyclones should be greater than that of anticyclones, since the main mass of air of the one has a component toward, and of the other from, the adjacent pole.

A statistical test of this conclusion is not at hand, but it seems to accord with inspection.

h. Since, as here conceived, the storm involves the general circulation from the surface to its top—that is, all the air up to the stratosphere—it seems possible that the pressure contrasts between " low " and adjacent " high " may also extend to this level.

Even this inference is supported by much observational evidence.[53]

i. Since, according to the conception here offered, the atmosphere of the particular type of cyclone under discussion is mechanically rather than thermally expanded, and since the swift winds of the front would tend to draw upward and out such air as leaks into the " low," it seems that the atmosphere of a cyclonic region might be warm in the east quadrant, but cold in the centre and other quadrants.

j. Since, according to this conception, the winds to the west of a cyclone are from higher latitudes, it follows that they must spread out, coming where meridians are more separated, with the upper portions flowing to lower levels, and also, because flowing toward the equator, must lag behind and thus by a damming up process build, or at least tend to build, a " high " in which the temperature of the bulk of the atmosphere, because of its downward component, shall be relatively warm.

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[53] Dines, *Jr. Scot. Meteorol. Soc.*, **16**, p. 304. 1914.

k. The expansion of the lower air (below the stratosphere) in the "low" and compression in the "high" leads to lowering and warming the stratosphere over the cyclone, and raising and cooling it over the anticyclone. The difference in intensity of radiation by the moist and dry air of the two regions probably accentuates these conditions.

All the several inferences under *i*, *j*, and *k* (doubtful, because unsupported by analysis) are fully in accord with observations, whatever the physical cause or causes may be. This is shown by Figs. 16 and 17, which give respectively the vertical temperature gradients for winter and summer in regions of high (765 mm. and up), neutral (757.5 mm. to 762.5 mm.), and low (755 mm. and less) pressure, as determined by sounding balloons from Lindenberg, Munich, Strassburg, Trappes, Uccle, and Zurich. The figures of the legend give the number of flights from which the curves were determined. Abundant additional evidence of these formerly unsuspected temperature relations between the cyclone and anticyclone is given by Wagner,[54] Gold,[55] Dines,[56] and others. They must therefore be accepted as definitely established for the British Isles and Continental Europe, and tentatively accepted (until disproved if not true) for other parts of the world.

Probably the above conceptions of the mechanism of the average extra-tropical cyclone could be elaborately developed from the standpoint of hydrodynamics and thermodynamics, but this would be too tedious to include here. The concept, however, even without such support, may be useful in helping to remember the chief facts learned by recent free air observations.

"*Tropical.*"—As previously stated, a considerable percentage of the tropical cyclones (the actual number probably is only 2 to 3 per year in the northern hemisphere) migrate to extra-tropical regions. Shortly after recurving they gradually lose their original characteristics and become extra-tropical in type as well as location. Nevertheless, they generally still are called "tropical cyclones" (West India hurricanes, typhoons, etc.), however high the latitude actually reached. A causal name is not suggested for this cyclone, for the reason that it is not certain what is the chief factor in its origin.

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[54] *Beiträge zur Physik der freien Atmosphere*, **3**, 57, 1909.

[55] "International Kite and Balloon Ascents," 1913. (Geographical Memoirs, No. 5.)

[56] *Jr. Scot. Meteorol. Soc.*, **16**, p. 304. 1914.

As already explained, these storms originate usually, if not always, in the doldrums, where the air is quiet, hot, and excessively humid. The stillness of the air, if long continued, leads to a high degree of humidity, and the humidity, in turn, decreases the local pressure and also increases the absorptive power of the atmosphere for both solar and terrestrial radiation. Hence an inwardly directed pressure gradient and a corresponding circulation, the latter greatly facilitated wherever opposing trade winds exist, are slowly established. The resulting precipitation, through the latent heat thus set free, if sufficiently abundant and properly distributed, accentuates the circulation and thus secures the perpetuation of the cyclone until it fails for want of moisture, as it often does on dry land, or spreads and loses itself in the world circulation. As it recurves and gets well away from the tropics, it generally spreads out, becomes less intense, has most of its precipitation on the east side, and otherwise gradually acquires the characteristics of a cyclone of extra-tropical origin, and, presumably, is maintained in the same way. The physical cause of these storms, if they originate, as seems probable, in the doldrums and between counter trades or similar winds, appears to be partly thermal and partly mechanical, and their subsequent maintenance, after reaching the middle and higher latitudes, the same (largely mechanical) as that of any other cyclone of the same place.

ANTICYCLONES.

Anticyclones, or "highs," are divisible, with respect to their genesis, into two classes: (1) Mechanical: *a*, permanent, and *b*, migratory. (2) Radiational: *a*, permanent; *b*, semipermanent; and *c*, transitory.

In this classification the relative "high" that obtains over an entire hemisphere during its winter, and also those seasonal highs of continental (during winter) and oceanic (during summer) extent, have all been excluded. Like the lows of similar great size, they only modify somewhat the course of the general circulation and give direction to monsoon winds.

Mechanical (Permanent).—Since the surface of the ocean is a gravitational equipotential surface, it follows that west winds, by virtue of their excess centrifugal force, will tend to climb up the bulge of the earth toward the equator, and east winds, because of deficiency in centrifugal force, will tend to slide down this bulge toward the nearest pole. Hence along the borders, between trade winds and the west winds of adjacent higher latitudes, the atmosphere must be subject to a mechanical squeeze. In other words, mechanically produced high pressure belts must encircle the earth at about latitudes 30° to 35° N. S. They must also be best developed over the oceans, where the trade winds, upon which they largely depend, are strongest and steadiest. These belts are clearly shown in Fig. 48.

Mechanical (Migratory).—The migratory anticyclone referred to here, and assumed to be generated in the manner explained in the discussion of mechanical cyclones, is the common one of middle latitudes. The directions of its system of winds, but in no sense the complete paths of the air particles, are given by synoptic charts. These directions are spirally outward, clockwise in the northern hemisphere, counter-clockwise in the southern. Hence the relation of anticyclonic wind velocity to horizontal pressure gradient is given by the equation,

$$\frac{dp}{dn} = v\left(2\,\pi \sin\varphi - \frac{v}{r}\right).$$

in which r is the radius of curvature, nearly, of the wind-path at the place considered, and the other symbols have the usual significance as previously given. From the negative sign it appears that for a given radius of curvature the possible wind velocity in a " high " is strictly limited, whatever the pressure gradient.

Velocity and Path of Travel.—The velocity and normal path of the migrating anticyclone are by no means as well known as those of the cyclone, except, perhaps, through the studies of Bowie and Weightman [57] in respect to those that cross the United States. However, the size, frequency, and velocity of travel of anticyclones are all roughly the same as those of similarly located cyclones. Furthermore, their most frequented paths, though, perhaps, generally beginning at higher latitudes over continents and running to lower over the oceans than the similar cyclonic routes, are roughly parallel thereto.

Just why these close relations hold is not certain. It may be interesting, however, to note that they appear to support the above assumption that generally the migrating cyclone and its neighboring westerly anticyclone are correlative parts of a single great atmospheric disturbance.

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[57] *M. W. R. Supplement*, No. 4, 1917.

Wind Velocity.—The actual velocity of the wind in the different quadrants of an anticyclone and at different elevations is given in the following table by Peppler,[58] based on a large number of observations made during 1903–1909, at Lindenburg; latitude, 52° 10′ N.; longitude, 14° 15′ E. Probably other mid-latitude regions have approximately the same anticyclonic wind velocities, but this is not certain, nor are there at hand sufficient data to determine the question.

Anticyclonic Wind Velocity in Metres per Second and (Miles per Hour).

Altitude		Surface 122 m.	500 m.	1000 m.	1500 m.	2000 m.	2500 m.	3000 m.	3500 m.	4000 m.
South quadrant	Winter	4.43 (9.9)	8.48 (19.0)	8.82 (19.7)	8.68 (19.4)	8.60 (19.2)	8.92 (19.9)	9.71 (21.7)	10.14 (22.7)	10.97 (24.5)
	Summer	3.92 (8.7)	6.19 (13.9)	6.25 (14.0)	6.36 (14.2)	6.17 (13.8)	5.97 (13.3)	6.19 (13.9)	7.08 (15.9)	7.83 (17.5)
	Year	4.16 (9.3)	7.32 (16.4)	7.52 (16.8)	7.51 (16.8)	7.38 (16.5)	7.44 (16.7)	7.94 (17.8)	8.60 (19.2)	9.39 (21.0)
West quadrant	Winter	3.93 (8.8)	7.60 (17.0)	7.19 (16.1)	7.35 (16.4)	7.23 (16.2)	7.21 (16.1)	7.57 (16.9)	7.75 (17.3)	8.11 (17.9)
	Summer	3.39 (7.6)	5.26 (11.8)	5.41 (12.1)	5.18 (11.6)	5.28 (11.8)	5.39 (12.1)	5.20 (11.6)	4.74 (10.6)	5.04 (11.3)
	Year	3.74 (8.4)	6.51 (14.5)	6.38 (14.3)	6.35 (14.2)	6.34 (14.2)	6.38 (14.3)	6.46 (14.4)	6.32 (14.1)	6.65 (14.9)
North quadrant	Winter	4.21 (9.4)	9.69 (21.7)	9.54 (21.4)	9.78 (21.9)	10.19 (22.8)	10.69 (23.9)	11.59 (25.9)	12.29 (27.5)	14.43 (32.3)
	Summer	4.05 (9.0)	7.01 (15.7)	7.68 (17.2)	8.41 (18.8)	8.85 (19.8)	9.51 (21.3)	10.04 (22.5)	10.68 (23.9)	11.45 (25.6)
	Year	4.13 (9.3)	8.35 (18.7)	8.61 (19.2)	9.09 (20.4)	9.51 (21.3)	10.09 (22.6)	10.80 (24.2)	11.47 (25.6)	12.92 (28.9)
East quadrant	Winter	4.29 (9.6)	8.24 (18.4)	8.83 (19.8)	9.56 (21.4)	10.92 (24.4)	12.44 (27.8)	13.52 (30.2)	14.02 (31.3)	15.68 (35.1)
	Summer	3.92 (8.7)	5.88 (13.2)	6.42 (14.3)	6.55 (14.6)	6.98 (15.6)	7.54 (16.9)	7.31 (16.3)	7.83 (17.5)	8.28 (18.5)
	Year	4.06 (9.1)	7.01 (15.7)	7.57 (16.9)	8.00 (17.9)	8.89 (19.9)	9.93 (22.2)	10.35 (23.2)	10.86 (24.3)	11.91 (26.6)

Radiational (Permanent).—There are two extensive regions, Antarctica and Greenland, where the barometric pressure always is high. At each place the high pressure appears to be the result of the very low prevailing temperatures, which in turn are due in part to the great elevations and in part to the free and abundant radiation from the snow surface through the comparatively clear skies, kept generally free from clouds by the descent of the upper air induced and maintained by the vigorous fallwinds. That surface radiation is an essential factor in establishing and maintaining these low temperatures is obvious from the fact that air cannot flow down hill, as it does in these regions, unless it has a greater density and therefore lower temperature than the adjacent atmosphere of the same level. It is also obvious from the prevailing and excessive surface temperature inversions, in which, and because of which, those ice fogs that doubtless furnish much of the interior precipitation are so common.

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[58] *Beiträge zur Physik der freien Atmosphäre*, 4, p. 95, 1911.

It will be well to remember in this connection that snow, in addition to being an excellent reflector and, therefore, poor absorber of solar radiation, is also a good emitter of those long wave-length ($12-15\ \mu$) radiations appropriate to its temperature. In this way the low temperatures are maintained, not only during winter when air circulation and, to some extent, cooling ice supply the only available heat, but also during the long-continued insolation of summer.

The air drainage thus produced is manifest in those strong and persistent southeast or anticyclonic winds that characterize the climates of the border and all explored portions of Antarctica, except, of course, near the pole, and, presumably, therefore, of the whole continent. Similar, though less vigorous, anticyclonic winds also prevail over and around Greenland. Each of these great regions but especially Antarctica, by virtue of its strong and continuous refrigeration, obviously is exceedingly effective in its influence on the atmospheric circulation of its respective hemisphere. If there were no such extensive high and snow-covered areas in the polar regions, it is clear that our general circulation would be less vigorous and doubtless very different in many places.

Radiational (Semipermanent).—As is well known, there are five semipermanent "highs," all of which occur on the oceans: Two, as Fig. 48 shows, about 35 degrees north of the equator and three about 32 degrees south of it. Two are on the Pacific Ocean—one west of southern California, the other off the coast of Chile; two on the Atlantic Ocean—near the Azores (known as the Azores "high") and off the coast of southern Africa; and one on the Indian Ocean, about half-way between Africa and Australia. A sixth oceanic "high" of this same class, but far less persistent than any of the above, often develops, especially during winter, in the region of the Bermudas.

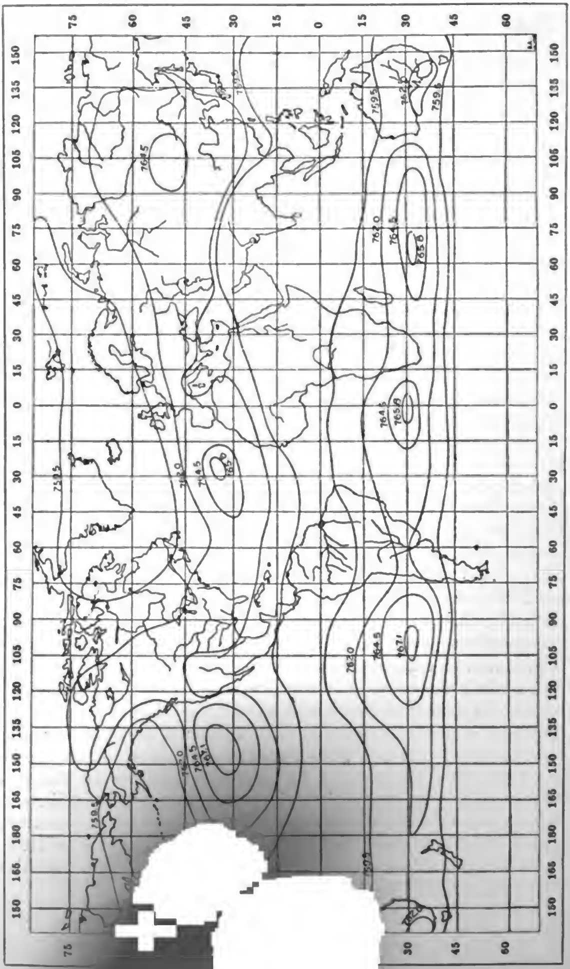
Obviously there must be a close relation between the intensities and locations of these highs and the directions and velocities of the surrounding winds, even to great distances, as shown by Figs. 49 and 50. Hence it is meteorologically important to form some conception in regard to their origin.

It will be seen from Fig. 48 that all these "highs" or centres of maximum pressure occur along the high-pressure belts, and from Fig. 51 that they occur at those places along these belts where the temperature of the air is low for that latitude; that is, where the isotherms are deflected equatorward. At these places, then, there are two causes of high pressure: (*a*) the mechanical pressure that produces the high-pressure belts, as already explained, and (*b*) a relatively low surface temperature which allows the upper air to cool somewhat and correspondingly contract.

It is known from sounding balloon records that the temperature of the atmosphere even to great altitudes follows more or less closely any long-continued temperature changes of the surface. Hence one might reasonably expect the atmosphere over the cold regions, as shown by Fig. 51, to be colder at every level than that of the surrounding atmosphere over warmer regions. A change of 1° C. throughout would change the pressure by 2 mm. or more. Hence, since the regions in question, according to Buchan's charts, are from 1° C. to 3° C. colder than those of the same latitude east or west, it appears that the pressure maxima of 2 mm. to 6 mm. probably are due to the continuous relatively low surface temperatures. In this case the "high" appears to be due to the cooling of the superincumbent atmosphere to that temperature at which its radiation is in substantial equilibrium with the minimum radiation from below.

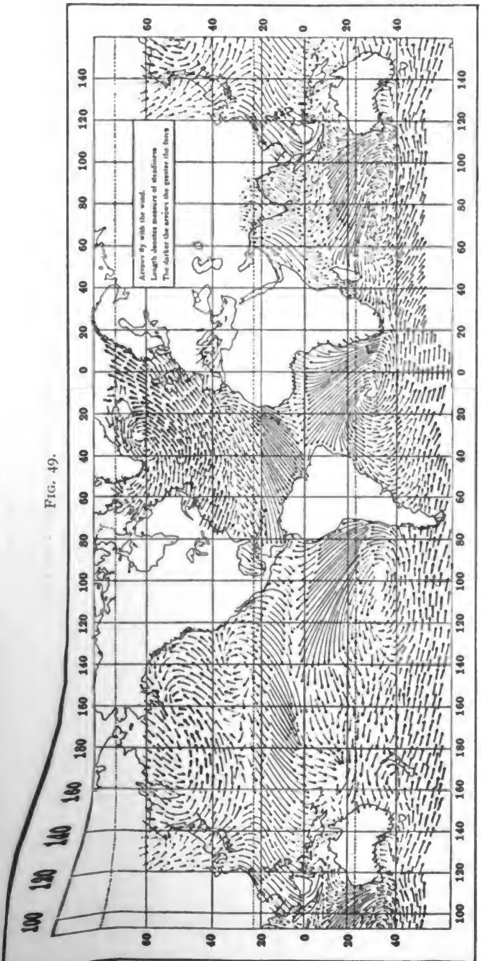
But what is the cause of the local low surface temperatures? Referring to Fig. 52, it will be seen that there are five different places, and only five, where a distinctly cold ocean current crosses a belt of high pressure, and that every one of these is associated with a region of maximum pressure. Neither is there a semi-

Fig. 48.



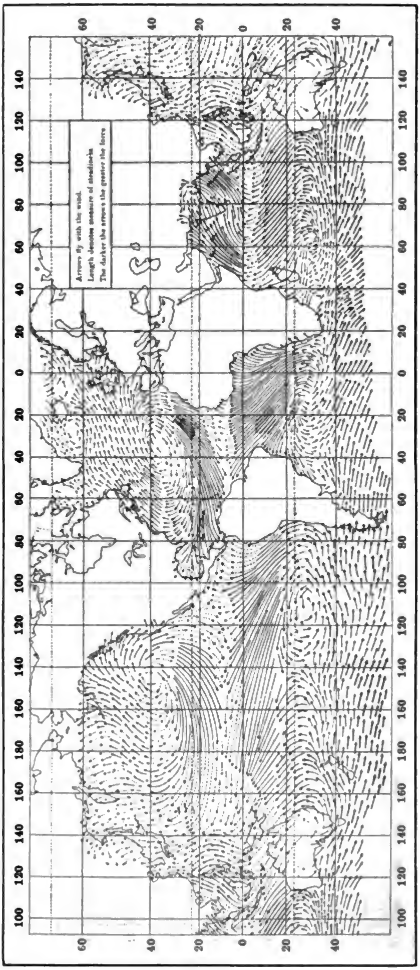
Annual average isobars. (After Buchan.)

FIG. 49.


Arrows fly with the wind.
Length denotes measure of steadiness.
The darker the arrows the greater the force
60
40
20
0
20
40
140
120
100
80
60
40
20
0
20
40
60
80
100
120
140
160
180
160
140
120
100

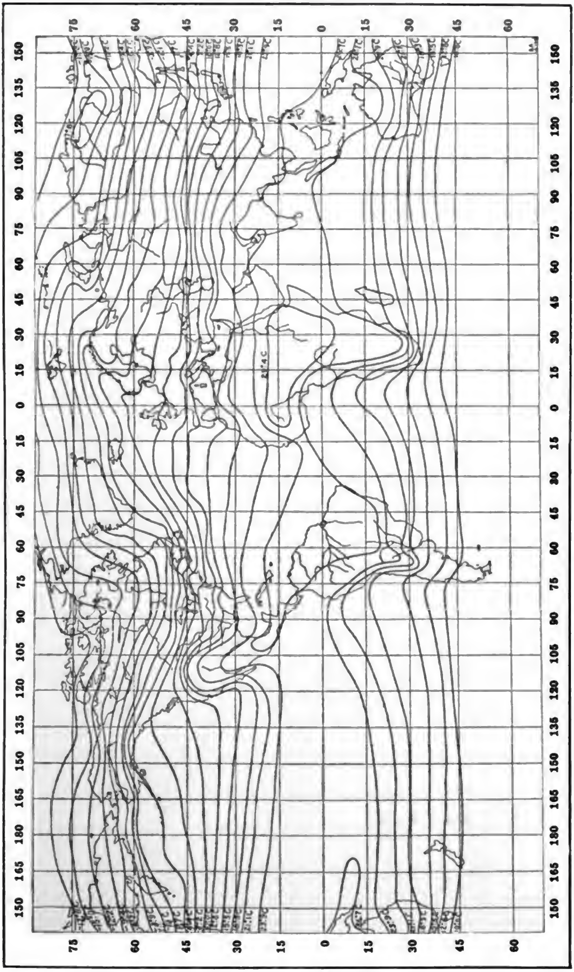
Ocean winds, January and February. (Köppen.)

Fig. 50.


Arrows fly with the wind.
Length denotes measure of steadiness
The darker the arrows the greater the force
140 120 100 80 60 40 20 0 20 40 60 80 100 120 140 160 180 160 140 120 100
60 40 20 0 20 40

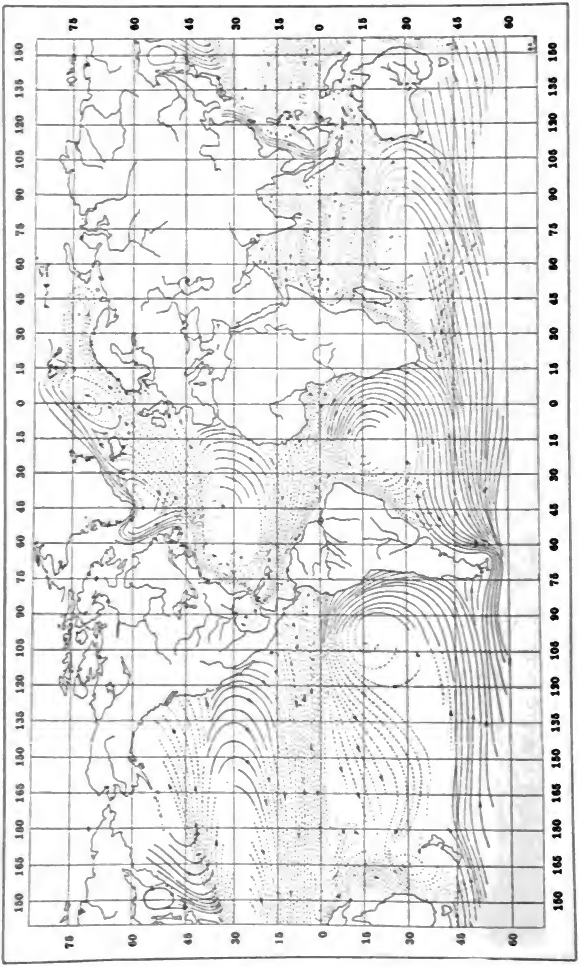
Ocean winds, July and August. (Köppen.)

FIG. 51.



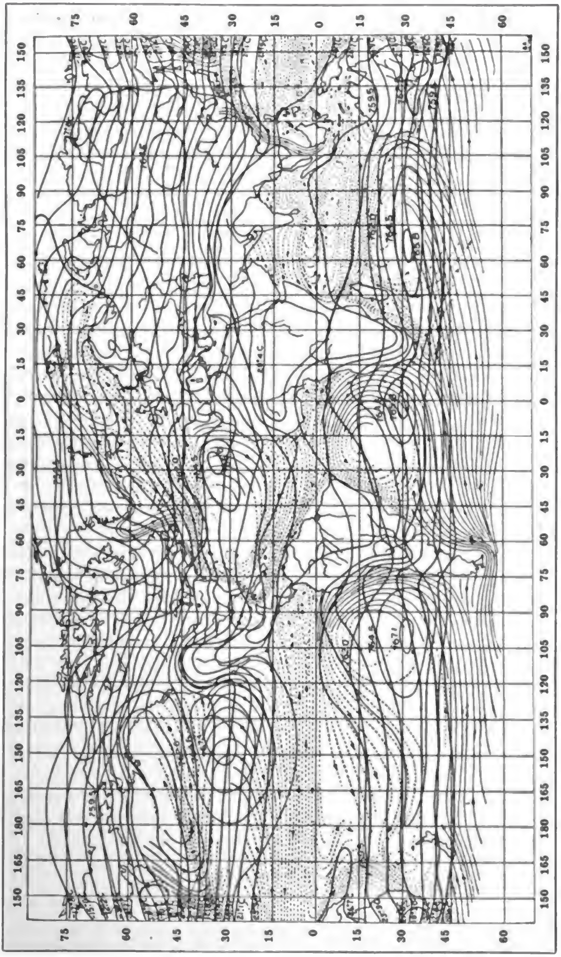
Annual average isotherms. (After Buchan.)

Fig. 52.



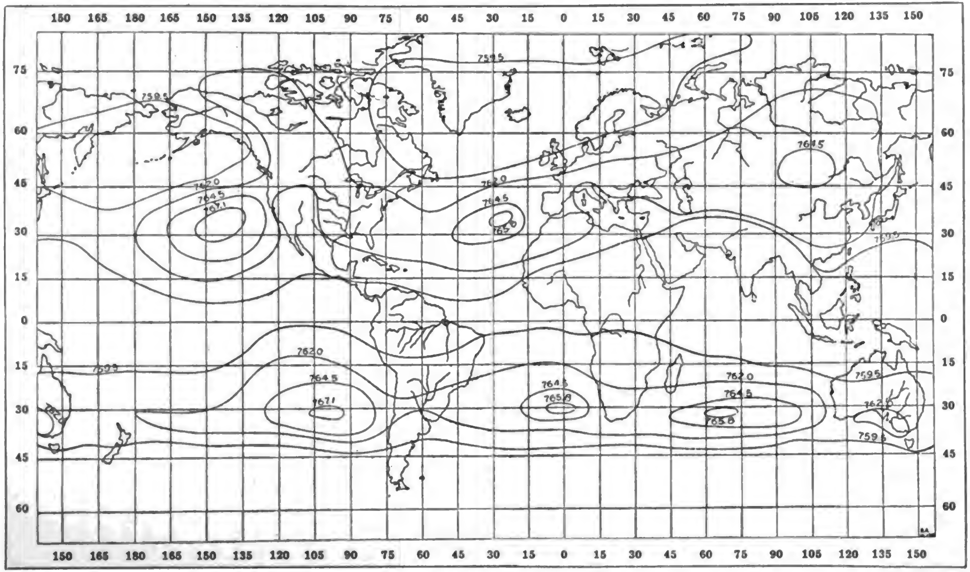
Ocean currents.

FIG. 53.



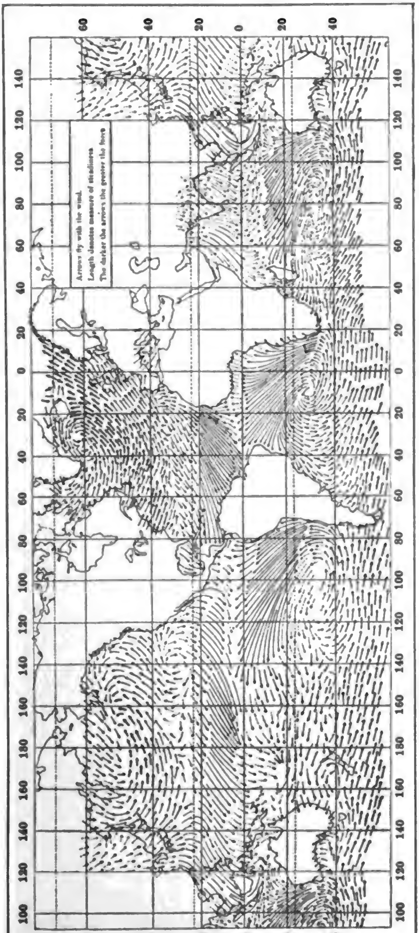
Ocean currents, annual average isotherms, and annual average isobars.

FIG. 48.



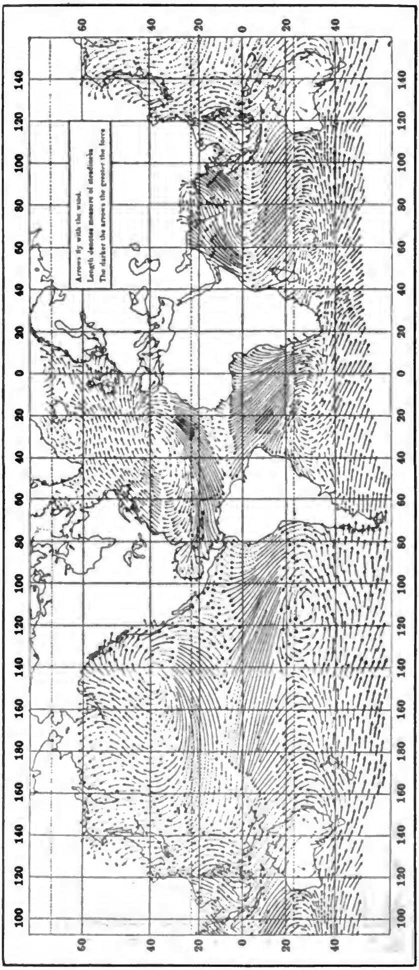
Annual average isobars. (After Buchan.)

FIG. 49.


Arrows fly with the wind.
Length denotes measure of steadiness.
The darker the arrows the greater the force.
140
120
100
80
60
40
20
0
20
40
60
80
100
120
140
160
180
160
140
120
100
60
40
20
0
20
40

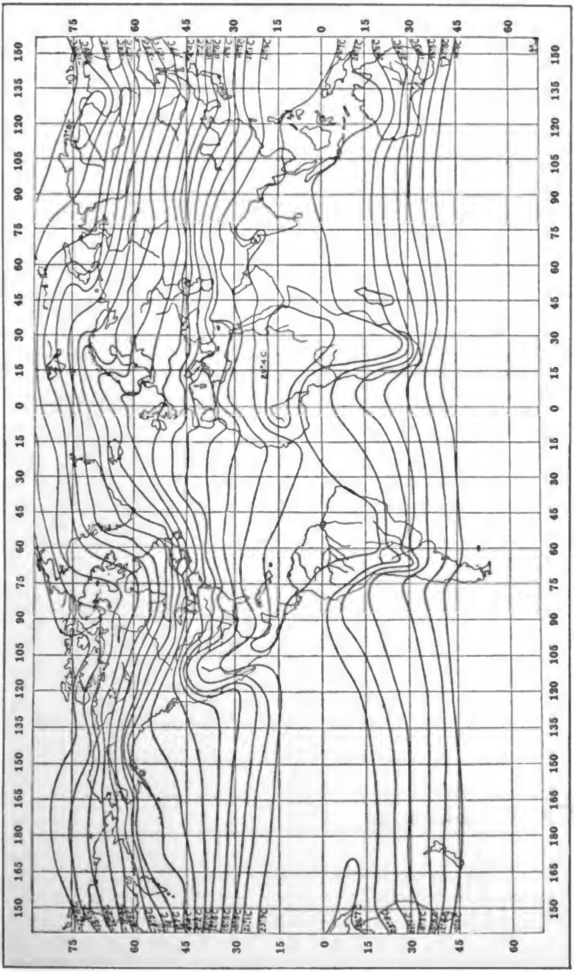
Ocean winds, January and February. (Köppen.)

Fig. 50.


Arrows fly with the wind.
Length denotes measure of steadiness.
The darker the arrows the greater the force.
60
40
20
0
20
40
100
120
140
160
180
160
140
120
100
80
60
40
20
0
20
40
60
80
100
120
140

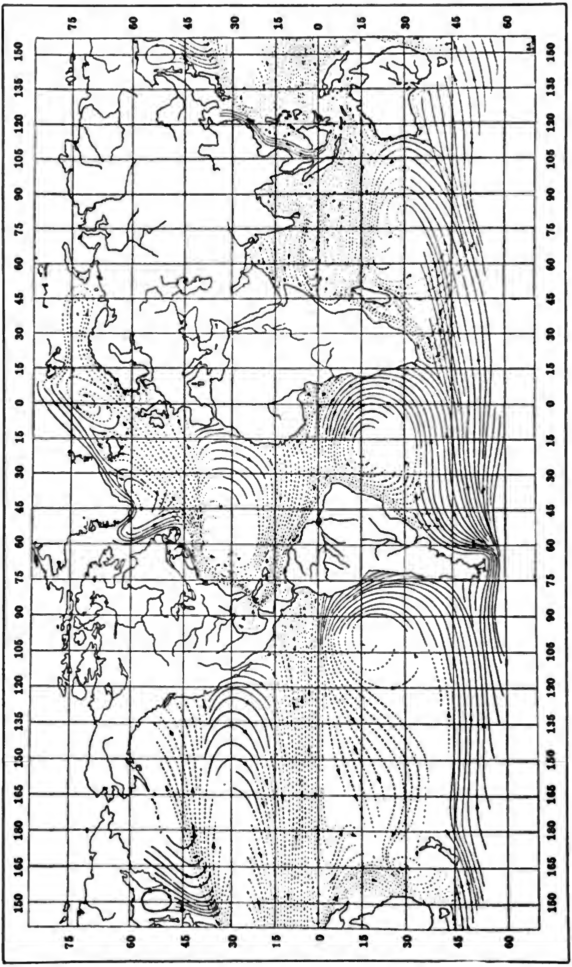
Ocean winds, July and August. (Köppen.)

FIG. 51.



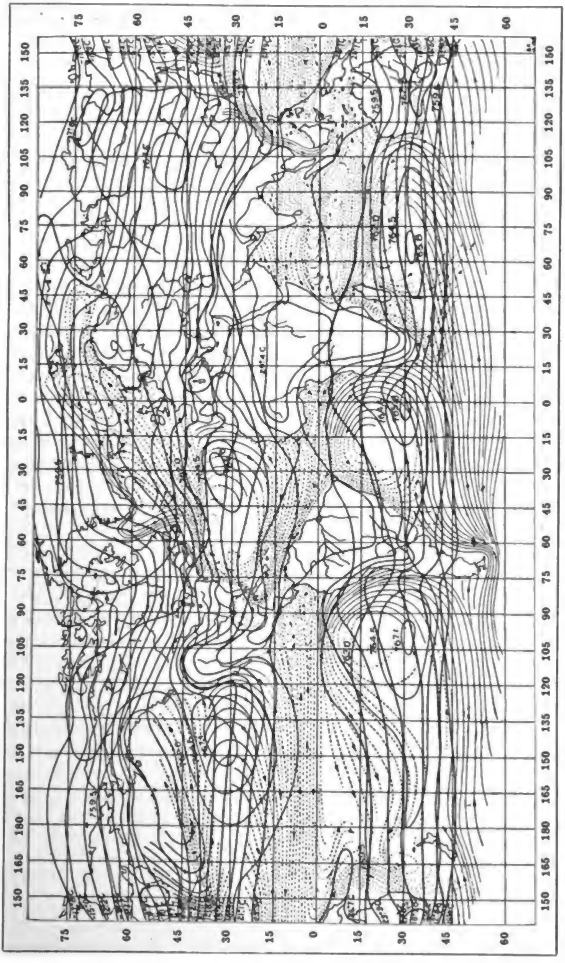
Annual average isotherms. (After Buchan.)

FIG. 52.



Ocean currents.

FIG. 53.



Ocean currents, annual average isotherms, and annual average isobars.

permanent "high" anywhere else on the oceans. Wherever, then, the mechanical effect that produces a belt of high pressure is reinforced by thermal contraction due to cold water, there, and only there, as illustrated by Fig. 53, are found a maximum of atmospheric pressure and the centre of a semipermanent anticyclone. During winter there is also a slight minimum temperature along the North Atlantic high-pressure belt near Bermuda, and a similar one along the South Pacific belt just east of New Zealand, and at each place a corresponding tendency to the maintenance of an anticyclone.

One obvious effect of all these semipermanent highs is the location of branches or channels of interzonal circulation, analogous to those of the cyclones and anticyclones of higher latitudes. Thus, much tropical atmosphere, in addition to that carried by the counter-trades, reaches middle latitudes by flowing around and to the west of the semipermanent "highs." From here the next stage in the general circulation takes the air to still higher latitudes, and even to polar regions, around and to the east either of the semipermanent "lows" or of the migratory cyclones. In its return it passes to the west of the "lows" or east of the travelling "highs," and finally around and to the east of the semi-permanent "highs." These, however, are only general channels and, presumably, average routes, upon which are superimposed innumerable and ever-changing irregularities.

Radiational (*Transitory*).—During winter elevated snow-covered regions often become very cold and thus build "highs" similar to those of Greenland and Antarctica, though usually much smaller in extent, as well as only temporary. Occasionally these give rise to strong and cold surface winds, especially when the existing gradient is accentuated by the passage of a well-developed cyclone along lower latitudes. Examples of such winds are the mistral of the Rhone Valley and the bora of the Adriatic and Black Seas. The Texas norther and, probably, the blizzard of the Great Plains are other and important examples of the drainage of transitory radiational anticyclones. The well-known violent fallwind of the coast of Norway appears to have a similar origin, as indeed have innumerable other drainage winds in all mountainous and high plateau regions outside the tropics.

FORCED WINDS.

Although in greater or less measure all winds are interdependent, only a relatively small number obviously are generated and maintained by other and coexisting winds. Among these are eddy winds, foehn or chinook winds, and, presumably, the winds of the tornado and waterspout.

Eddies.—Wherever the wind blows across a steep-sided hill or mountain, eddies are likely to be formed, especially on the lee side. In such cases the direction of the surface wind is approximately opposite to that of the general or prevailing wind, with a calm between them.

For the practical purpose of the weather forecaster, wind eddies have but little significance, except in one important particular. He must exclude from his forecasting data all reports of wind direction obtained at places where eddies are likely to prevail. Such eddies, however, may be of great importance to the aviator, since they produce, on their forward sides, troublesome down-currents and also shallow surface winds which, because oppositely directed to the winds, less, perhaps, than 100 metres above, may render landing at such places difficult or even very dangerous.

Foehn, Chinook.—The foehn, or chinook, as it generally is called in North America, is a warm, dry wind blowing down a mountain side onto the valleys and plains beyond. It differs from the typical fallwind in being warm, level for level, and not cold, as is the latter, in comparison with the air of surrounding regions.

Any system of winds, whether of trade, cyclonic, or other origin, extending to or near to the surface and blowing more or less normally across a mountain ridge, necessarily induces up-currents, dynamically cooled, on the windward side and down-currents, adiabatically heated, on the lee side, except along the under portions of such eddies as may be produced, where the directions and consequent temperature changes are just the reverse. Therefore:

1. Foehns occur at all seasons.
2. The relative humidity of the foehn is always low.
3. The rise in temperature is greatest when the original vertical temperature gradient is least; hence greatest, other things being equal, *a*, when the upper air is warmest—that is, when there has been precipitation to the windward; *b*, when the surface air is

coldest—that is, when there has been free night radiation (clear skies) on the lee side; and *c*, during winter, when the vertical temperature gradient through the first several hundred metres may be only 4° C., say, per kilometre, instead of the usual 7° to 8° C. of summer.

Since foehn winds often are swift and the heating rapid, it follows that the most pronounced of them are quite likely to be accompanied also by frequent but irregular convections and, therefore, strong gusts, swirls, and general turbulence. Under favorable conditions a foehn may even develop a secondary "low," the primary, of course, being on the same side of the mountain.

TORNADO.

The tornado,[59] in which the air travels in approximate circles, as its name implies, is well nigh peculiar to the United States east of the Rocky Mountains. Nor is it at all equally distributed over even this area, since it occurs rarely in the Alleghenies, seldom along the Gulf and Atlantic coasts, frequently in central and northern Alabama, Georgia, and South Carolina, frequently also in Ohio, Indiana, Illinois, and southern Michigan, and most frequently in Missouri, Kansas, and Iowa.

The tornado develops only in connection with a thunderstorm, usually just in front of the rain, and especially in connection with those particular storms that form along a valley "low," or between V-shaped isobars where opposing winds of widely different temperatures give rise to that exceptionally strong vertical convection essential to the genesis and growth of the thunderstorm. The season of most frequent occurrence, therefore, is spring and early summer; in fact, during winter it is unknown, except occasionally near the Gulf and in other warm sections. Similarly, the time of most frequent occurrence is 3 to 5 P.M. Also, since it is only a local phenomenon, while the conditions favorable to its genesis are much more extensive, it often happens that a number of tornadoes develop, even close together, in connection with a single distorted cyclone.

The diameter of the tornado averages only about 300 metres (984 feet): the length of its path varies roughly from 100 metres to possibly 500 kilometres (328 feet to 310 miles); its direction of travel is nearly always northeast; its rate of travel, though differing greatly, averages roughly 11 metres per second (25 miles per hour), thus passing a given place in half a minute or less; while its winds, always counter-clockwise, are the swiftest known, estimated at 45 to 225 metres per second (100 to 500 miles per hour). It is therefore by far the smallest, briefest, and severest of all storms. Essentially it is a phenomenon of the middle atmosphere. In its genesis clouds whirl around each other with great velocity and turmoil, while from beneath their centre a funnel-shaped cloud develops, usually tapering off to a long pendent spout that may or may not extend to the earth. Wherever it does reach the surface it produces a deafening roar, and practically everything in its immediate narrow path that can be blown down or torn to pieces is destroyed, though generally but little damage is done on either side. On the other hand, wherever it does not come to the surface its passage produces but little or no effect.

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[59] For detailed discussion see: Finley, "Tornadoes," New York, 1887, and Ferrel "A Popular Treatise of the Winds," New York, 1889.

Cause.—From the characteristics of the tornado and from the meteorological conditions that normally accompany it, it appears that its origin must be purely mechanical. Thus its rotation obviously is derived essentially from that of the cyclone in which it occurs, since it is always in the same sense, counter-clockwise, however small its diameter, and never clockwise, as is often the case with large dust-whirls when formed in still air. But how is the rapid rotation started? From the directions of the V-shaped isobars it is clear that at a kilometre or so above the surface there must be neighboring winds flowing in approximately opposite directions and, of course, more or less intermingling and overrunning counter currents. Hence, under such conditions, the inflow occurring at various levels that feeds the strong up-draft always just in front of a thunderstorm must occasionally so deflect these counter currents and bring them so closely together as necessarily to produce a violent whirl.

Here, too, as in all other cases of atmospheric motion, the law of the conservation of areas, or the constancy of the product of radius of curvature by linear velocity, applies, except as modified by friction and viscosity. Hence, as the radii of curvature of the opposing currents may at first be comparatively large, and after the deflection relatively small, it follows that the wind velocity within the whirl, in which both the counter currents are taking part, may be very great. This rotation, however, does not check the up-current, hence that convection which is essential, as explained above, to the rotation is maintained, and therefore the rising currents brought in spirally with increasing angular and linear velocity as the axis of spin is approached. Each filament, so to speak, of the spirally rising air viscously drags along its under and slower neighbors, thereby bringing them nearer the axis and increasing their velocity. In this manner the whole of the rising column is set whirling with greater or less spin. Around the axis of rotation the pressure obviously is reduced in proportion to the centrifugal force, the temperature correspondingly lowered, and therefore a cloud spout often formed.

Wherever the inflow of the surface air is greatly checked, or its course so altered by a deflecting hill or other obstacle as greatly to decrease the spin, there the tornado must lift. It may, however, retain its full vigor in the unaffected upper air, and soon reach the surface again.

Why Essentially Peculiar to the United States.—Since the tornado rarely occurs in violent form except in that portion of the United States which is east of the Rocky Mountains, it follows that that combination of meteorological conditions essential to its genesis seldom obtains in other parts of the world. This combination appears to be very simple—only a vigorous convection between strong neighboring counter currents. But since vertical convection, as indicated by thunderstorms, is common enough in most parts of the world, it follows that the other factor —namely, strong counter currents—is the distinctly American phenomenon. That such currents should often occur east of the Rocky Mountains is obvious from the position and trend of these mountains themselves, giving rise to southward winds, and the location of the Gulf of Mexico, from which winds turn northward. No other similar combination of mountain and ocean wind controls exists, and therefore no other place has in all respects the same kinds, frequencies, and intensities of storms.

Waterspouts.—Only its well-established name requires that the waterspout shall be specifically mentioned, since mechanically it does not differ essentially from the tornado. In fact, a tornado becomes a waterspout as soon as it passes to sea, while a waterspout becomes a tornado immediately it invades the land.

The waterspout, like the tornado, originates well up in the atmosphere, and is especially frequent in those regions where adjacent winds, usually the one above the other, have different directions; hence where the counter trades, overrunning the trades, occur at ordinary cloud or convection levels; along the belt of doldrums, when considerably removed from the equator and flanked by opposing trade winds; and along boundaries of sharp temperature contrasts, such as the northern border of the Gulf Stream. In all such regions vertical convection may induce a more or less violent whirl in the same manner as that explained in the discussion of the tornado.

Occasionally small whirlwinds start from the surface of lakes or other bodies of water during calm hot weather. The strongest of these produce cloud columns, due to expansion, and are often called "waterspouts," though of radically different origin from that of the waterspout above described.

(To be continued.)

Reinforced-concrete Building with 2000-pound Floor Load. ANON. (*Engineering News-Record,* vol. 79, No. 23, p. 1065, December 6, 1917.)—Floor loads of 1000 and 2000 pounds per square foot as a maximum and 600 pounds as a minimum are an unusual condition provided for in the design of a reinforced-concrete warehouse and factory building now being erected in Chicago. These exceptionally heavy loads are due to the storage of steel plates and bars, while the lighter load is to provide for the reaction due to the operation of large punch presses. The building is approximately 45 x 75 feet, with five stories and a basement.

The heaviest loading will be for a width of 12 feet along one side of the second story where steel bars will be stored. This portion of the floor, about 33 per cent. of the floor area, is designed for a load of 2000 pounds per square foot. Support is provided by 12-inch concrete partition walls which are built on foundation girders and extend to the bottom of the heavily-loaded portion of the second-story slab. In the basement and the first story these walls are utilized to support racks for the storage of steel rods. The racks are composed of rows of heavy pipes embedded in the walls and projecting 18 inches on each side. The remaining 67 per cent. of the second story and the entire area of the first story are designed for a load of 1000 pounds per square foot. The three upper floors are designed for 600 pounds per square foot. The foundation, a concrete slab laid directly upon the clay, is surmounted by girders running in both directions. The interior columns are located at the intersections of these foundation girders.

Mazda Lamps for Motion-picture Projectors. L. C. PORTER. (*General Electric Review*, vol. 20, No. 12, p. 979, December, 1917.)—For a long time it was thought impracticable to apply incandescent lamps to large motion-picture projectors, and the arc lamp has had the field to itself. There were several reasons for this. The crater of the arc in common use as a light source for motion-picture projectors operates at about 130 candle-power per square millimetre; whereas the tungsten filament of a Mazda lamp at the melting-point emits only 79 candle-power per square millimetre, and at practical operating temperatures about 34 candle-power per square millimetre. Further, the condensers in common use utilize a solid angle of light of about 32 degrees. This angle includes a high percentage of the light flux from an arc due to the light distribution characteristic of the arc, whereas with the nearly spherical light distribution of the Mazda lamp this becomes a small proportion of the available light flux. Again, the crater of the arc is a relatively solid homogeneous light source, and an image thereof projected upon the screen results in fairly even illumination, while with a Mazda lamp an enlarged image of the filament is projected, resulting in a very streaked screen.

These obstacles, though seemingly great, have been overcome. The enormous difference in brilliancy of the two sources was lessened by developing a new type of Mazda lamp and a new lens system. Of these components, the condenser plays the most important part in solving the problem. It was found impracticable to make a plano-condenser of sufficiently short focus. The difficulty was overcome by the design of a condenser somewhat similar to a semaphore lens; that is, a lens with steps or corrugations. With this condenser a solid angle of 75 degrees was intercepted, which immediately resulted in a very large increase in the light flux available. A further gain in illumination was obtained by the use of a spherical mirror placed back of the light source. This arrangement of condenser and mirror practically increased the useful angle to 150 degrees. The corrugations on the condenser also performed the useful function of breaking up the filament image, resulting in an even screen illumination.

Many types of lamps were tried, and the one chosen is provided with a filament consisting of four helices contained within a space 0.4 inch square and has a capacity of 750 watts at 30 ampères. With this current high brilliancy is secured with a life of 100 hours. A compensator with either a rheostat or a reactance control in the primary is employed to accurately control the current value, and so maintain the high efficiency without diminishing the life of the lamp by accidental increase of current. The 750-watt lamp replaces any alternating-current arc on the market and direct-current arcs up to 40 ampères, and will project pictures 12 feet wide on a white plaster or cloth screen, or 16-foot pictures on a metallic, fibre, or glass screen. A large reduction in operating cost as compared with arc lamps and better pictures are obtained.

MECHANICAL DIFFERENTIATION.*

BY

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Member of the Institute.

At first thought it would seem that mechanical differentiation is simply a reversal of mechanical integration, and that any instrument having the latter function might also be used for the former. A modicum of reflection will show, however, that the two are not necessarily even complementary. Differentiation with a planimeter would be impossible. As is well known, that instrument finds its main use in the evaluation of irregular areas. Its dial reading is meaningless until the tracing-point has returned to the starting position, when the reading stands for the summation of infinitely small rectangular strips swept over by the planimeter arm. This summing up of infinitesimal areas is exactly what integrating means. Differentiation, on the other hand, is the process of evaluating the rate at which one dependent variable changes with respect to a second independent variable, and no stretch of the imagination can conceive of a planimeter, the simplest piece of apparatus for integrating, being used for this purpose.

Any area whatsoever may be looked upon as a surface bounded by a closed curve, in which the curve shows the relation between two variables plotted upon coördinate axes. Or it may be regarded as the difference of two areas, as, for example, in Fig. 1, where the shaded area is the difference between the two areas *aBCDb* and *aBFDb*. Inasmuch as the two curves $f(x)$ and $\phi(x)$ do not coincide, they follow different laws, so that the planimeter reading is really the difference between the two definite integrals $\int_a^b f(x)\,dx$ and $\int_a^b \phi(x)dx$. The fact that the planimeter deals with definite integrals of this kind only renders it worthless for differentiation.

Other integrating machines exist, however, that are not limited in this way. The most notable of these is the Coradi integraph, an instrument well known in the scientific world for its remarkable accuracy and mechanical perfection. It, and instruments of its kind, record areas as a continuous process by drawing a curve in which each ordinate distant x from the origin represents to some scale the area under the given curve up to the corresponding ordinate. In Fig. 2 $F(x)$ is the given curve. It may be empirical or theoretical. If it be traced with the point of the integraph by starting at a and proceeding in the clockwise direction up to A, then through B and b back to a, the recording pen will trace a curve $\theta(x)$ similar to that shown below. In going from a to A with the tracing-point, the recording pen stays in position on the x-axis, but immediately upon leaving A the latter begins to rise and move forward with the tracing-point, its motion being controlled by a parallel mechanism in such a way that any ordinate $m'n'$ distant x from the origin represents the area S, limited by the corresponding ordinate of the given curve. In other words, the integraph and other instruments like it evaluate the integral $\int_a^x F(x)\,dx$.

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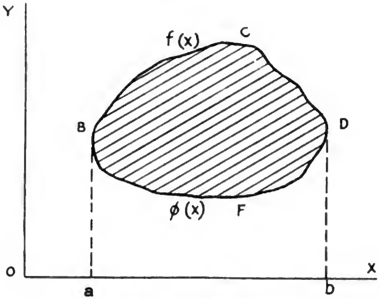
* Communicated by the Author.

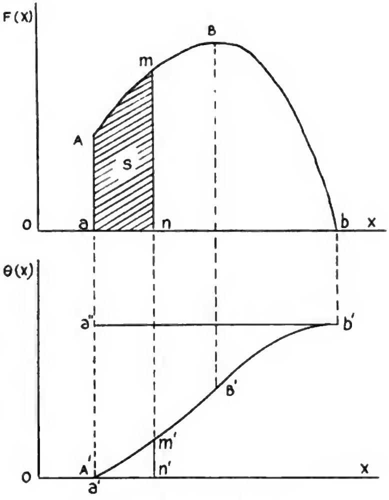
FIG. 1.



Integration with the planimeter.

Having followed the development of the so-called integral curve, we are in a position to consider the inverse operation; namely, that of obtaining the derivative curve of a given curve. Mechanical differentiation means nothing more than the drawing of the derivative curve of any experimental curve. Such a curve is shown in Fig. 2, for example, by ABb. Each ordinate of this curve represents to some scale the rate $\frac{dy}{dx}$, for the corresponding point on the given or primitive curve below it. Inasmuch as the derivative, $\frac{dy}{dx}$, at any point is shown graphically by the slope of the tangent at that point, it is obvious that the derivative or rate at *A′* is not zero. It is shown in the derivative curve by *Aa*. At *B′*, the point of inflection, the slope is a maximum, and at *b′* the primitive curve is horizontal, hence $\frac{dy}{dx}$ is zero and the derivative curve has come down to the *x*-axis. For the rest of the path from *b′* to *a″* the gradient remains zero, and the derivative curve here coincides with the *x*-axis.

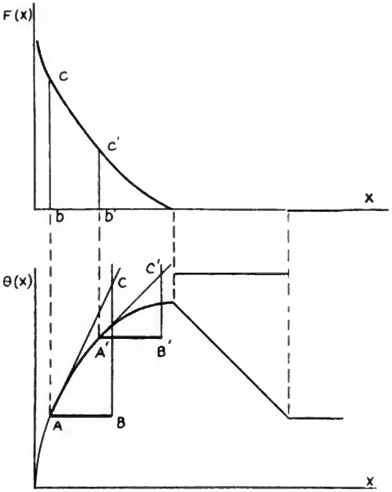
FIG. 2.



Derivative curve and its primitive.

A straight line making any angle with the horizontal has the same slope at all points along its length, hence its derivative curve is a straight line parallel to the *x*-axis. Any other straight line making a different angle with the horizontal would be represented by a line parallel to the *x*-axis at a distance greater or less than that of the first, depending upon its slope. The derivative curve for two such lines intersecting each other would consequently show a discontinuity at the point of intersection, so that for this particular point of the primitive curve the recording point would have to assume two positions. It is seen thus that any instrument for mechanical differentiation must provide for the two possible relative motions, one a horizontal motion of the recording-point while the tracing-point suffers both vertical and horizontal motion, and a second in which the recording-point may receive a vertical motion while the tracing-point remains in position but is rotated. With these two difficulties overcome, there still remains the necessity of a means for accurately determining the direction of the tangent at every point along a curve. The kinematics of the instrument once solved, it will be found that

FIG. 3.

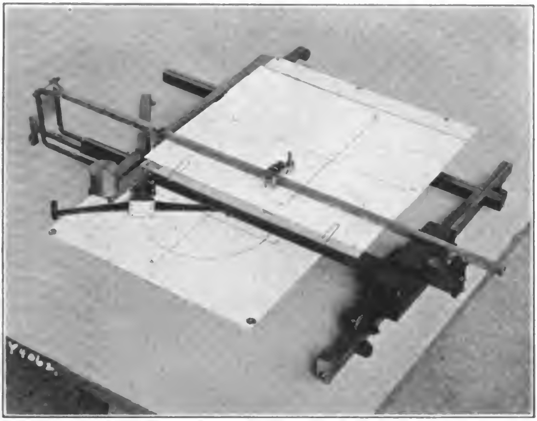


Method of obtaining the derivative curve.

usually a number of devices for orienting or locating the tangent may be used on the same machine.

While the method for obtaining the tangent at any point on a curve may seem of secondary importance, it is really very pertinent, since the accuracy of the machine is determined almost entirely by the accuracy and practicability of the orienting device. Five ways for drawing a tangent to a curve seem thus far to have been developed, any one of which may be applied by the designer of a differentiating machine to his problem. One of the first actually tried in mechanical differentiation was that of Professor J. Erskine Murray,[1] who used two small dots upon a sheet of celluloid at a distance of two millimetres apart. By placing this flat upon the drawing and turning it until the two dots just touched the curve, the tangent at this point of the curve coincided with a line drawn through the two dots. Somewhat similar to this is the means used in the attachment to the integraph

FIG. 4.



The author's first differentiating machine.

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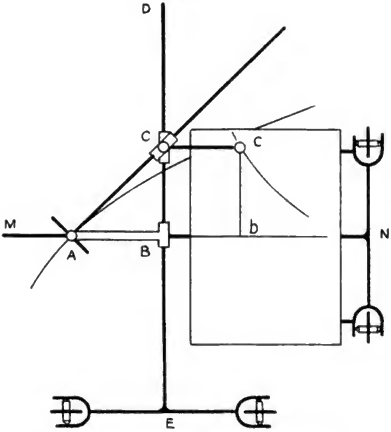
[1] *Proceedings of the Royal Society of Edinburgh*, 1904, p. 277.

for differentiating, by two ruled lines at right angles on a piece of glass which is placed upon the curve until one of these is tangent and the other normal to the curve at their point of intersection. A third and more common means for drawing the tangent is by locating the normal first, through the reflection in a mirror set vertically upon the drawing. When the curve and its image form a continuous smooth line without a cusp at their juncture the mirror is normal to the curve. To obtain a continuous record of the tangent, possibly the sharp disk is the most feasible. In coursing the curve with a small disk of this kind the tangent is continually maintained by the plane of the disk so long as the latter follows the curve. A fifth device is that of Guillery's[2] "aphegraphe." It depends for its accuracy upon the skill with which the operator can fit a metal strip or batten to the curve. A very thin lip of metal slipped into a suitable cut made at right angles to the face of a piece of mica completes an electric

FIG. 5.



Skeleton illustrating the Author's first machine.

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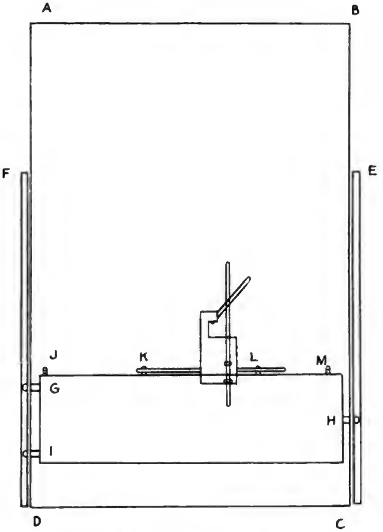
[2] *Mem. Soc. Ing. Civ. de France*, April, 1911.

circuit when by rolling the mica upon the batten, the lip, which is flush with the mica, comes in contact with the batten. The face of the mica is then tangent to the curve at the point of contact of the lip with the batten.

Having decided upon the device for locating the tangent, the next step in the design of a differentiating machine is the selection of a tangent base of constant length. In Fig. 3 such a base is shown by the two heavy horizontal lines AB and $A'B'$ of equal length. If this is the unit of measure, then the vertical distances BC and $B'C'$ intercepted by the tangents at A and A' directly measure the magnitude of the slope at these two points. The problem for the designer is the transferral of these distances mechanically to a suitable set of coördinate axes; for they also

FIG. 6.

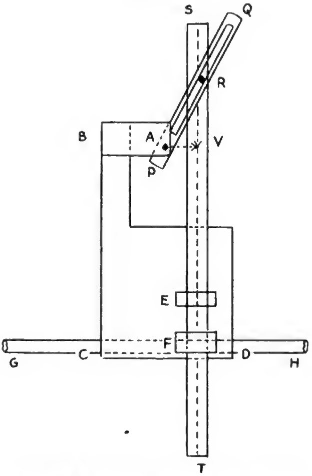


J. Erskine Murray's differentiating machine.

measure the derivatives at the respective points, since slope and derivative are identical. The resulting curve would then be the desired derivative curve. In the example *cc'* is the derivative curve of the primitive *AA'*, with *bc* equal to *BC*, and *b'c'* equal to *B'C'*.

These problems have all been met in a limited way by the author's first differentiating machine, shown in Fig. 4.[3] The various kinematical relations of this instrument are shown in the skeleton machine of Fig. 5. The mirror and the image of the curve are plainly visible in the first figure. In Fig. 5 the mirror is normal to the given curve at *A*. Two carriages are provided, running in grooves at right angles to each other. One

FIG. 7.



Transverse carriage of Professor Murray's machine.

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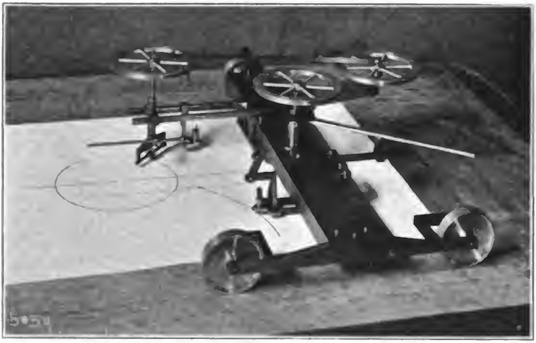
[3] For a detailed description of the differentiating machine, see *Scientific American Supplement* for February 12, 1916, or the *American Mathematical Monthly* for October, 1916.

of these carries a plate upon which is fastened the sheet of paper to receive the derivative curve. The link *AB* may move vertically along the bar *DE* and horizontally along the bar *MN*, fixed to the second carriage. The tangent base or link and the derivative curve are lettered to agree with the letters of Fig. 3.

Somewhat similar ideas are embodied in the instrument of Professor J. Erskine Murray, shown in Fig. 6.[4] The board *GHI* moves vertically in the side grooves *DF* and *EC* and carries the sheet of paper upon which the derivative curve is to be placed. The sliding rod, shown to a larger scale in Fig. 7 as *ST*, carries the recording pencil. The distance *RV* measures the derivative, and *AV* is the tangent base. The carriage *BD* may move horizontally in suitable guides fixed to the board *GHI* of Fig. 6.

FIG. 8.



The Author's latest differentiating machine.

Both machines described embody several undesirable features. First among these is the fact that the derivative curve must be drawn "point-by-point," necessitating a supplementary filling in with a pencil; secondly, the derivative curve is placed upon a different sheet of paper from that of the given curve; and, thirdly, motion is not constrained in the reverse direction, so that integration to check accuracy is impossible. It was with the view of eliminating these three disadvantages that the author reverted to the " integrating roller " so successfully used in the Coradi integraph for graphical integration. Final developments led to the construction of the machine illustrated in Fig. 8. Many structural features embodied in the integraph were used in its design on account of the long period of evolution of that instrument and its unqualified success for graphical work. To overcome the lost motion due to the peculiar hanging construction of the parallel mechanism of the integraph when reversed for differentiation, the system of three pulleys connected with a continuous wire was resorted to. On account of the need for extremely easy running conditions, the third point of support was removed from the differentiating carriage by using three running rollers, and the carriage was balanced to eliminate all side thrust that might introduce friction.

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[4] Reproductions are the original drawings published in the ***Proceedings of the Royal Society of Edinburgh*, 1904.**

FIG. 9.

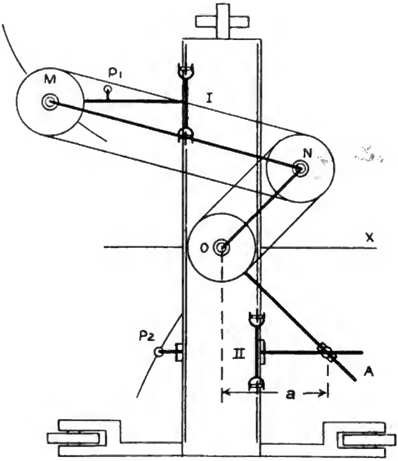

Diagram of the Author's latest machine.

The instrument is shown diagramatically in Fig. 9. By means of the parallel mechanism of three pulleys, the tangent bar OA is always kept parallel to the plane of the small steel disk with which the given curve is traced in differentiating, and which serves to give direction to the recording pen when integrating. Pulley M and the frame upon which the disk is mounted are both fixed to the same vertical shaft, so that this serves as the axis of rotation for the plane of the disk while rounding a curve. N is merely an idle pulley necessary on account of the variable distance from M to O. The distance a is the base or tangent constant. It may be changed by shifting the pivot on the arm extending out from the differentiating carriage II. An arm extends underneath the body of the machine from this carriage to the recording pen P_2 of Fig. 9, which draws the derivative curve of the curve followed by the steel disk. For integration, P_2 serves as a tracing-point and a pen attached to carriage I, shown as P_1, draws the integral curve.

While some difficulty attaches to the accurate tracing of the given curve with the disk, especially for the novice, the results obtained by the author when working slowly would substantiate a claim for the machine as being practical for drawing a continuous derivative curve. The tracing disk could also be removed and a mirror attachment added, or a ruled glass plate might be used similar to that described in the latest Coradi catalogue as an attachment for differentiation with the integraph by the point-by-point method.

On account of the uncertain mail delivery at the present time, it has not been possible to procure illustrations of the integraph attachments mentioned. The following quotation, taken in full from the catalogue of the famous Zurich firm, must therefore suffice as a description: "Device for differentiating, consisting of a cylindrical pin which fits in the sleeve of the drawing pen and carries a glass plate with engraved cross-lines which rests upon the plane; these cross-lines must be parallel to the X- and Y-direction, respectively, when the guide carriage [carriage to which the tracing point is attached when integrating, corresponding to the differentiating carriage of the author's machine] is in its normal position [the position for zero slope]. The pin fitting in the sleeve of the drawing pen is connected with the frame of the integrating roller by means of a parallelogram, so that when moving the guide carriage one of the cross-lines is always parallel to the plane of the integrating roller and to the direction rule. If a curve is to be differentiated, the cross-line is so placed on the curve by means of the guide carriage that the cross-line parallel to the direction rule is always parallel to the elements of the curve in question.

" Device for differentiating as described above, but having instead of the cross-lines a reflector resting vertically on the plane; this must always be rectangular to the X-line when the guide carriage is in its normal position, a proof of which is that the reflection of the *X-line* forms a straight (uninterrupted) continuation of the same. If a curve is to be differentiated, the mirror is so placed on the curve by means of the guide carriage that the reflection forms an uninterrupted continuation of the curve in question. The differential curve is, however, not traced by means of a continuous line, but by making dots at suitable distances with the tracer point of the guide carriage and afterward connecting these by hand with a pencil."

NOTE.—The author wishes to express his gratitude to the Department of Mathematics of the University of Wisconsin for its generosity in financing the construction of the instruments described in this paper.

MADISON, WISCONSIN, September, 1917.

Torpedoes. (*Bulletin of the New York Public Library*, vol. 21, p. 657, October, 1917.)—In the search for a method of defence against the highly developed and effective submarine torpedo, with whose destructive possibilities we are only too well acquainted, one of the first essentials to success is a thorough acquaintance with the state of the art. Quite recently much valuable bibliographical work has been done in this field, notably by Miss Helen Hosmer, whose contribution was published in the August, 1917, number of the JOURNAL, and Mr. David Rushmore, in the paper appearing in the *General Electric Review* for July, 1917.

Latterly the New York Public Library has taken up this work, and there appears in its monthly bulletin a most comprehensive chronological bibliography on torpedoes. The list includes devices from the earliest times to the present. With the unusual facilities afforded by this splendid library the list is undoubtedly the most complete at present available, and it should be in the hands of all those who are making a serious effort to find a solution of a critical problem of the hour.

A GRAPHICAL METHOD FOR THE CONSTRUCTION OF ELECTROSTATIC FIELDS.*

BY

SYLVAN J. CROOKER.

THE METHOD.

THE force at any point of an electric field is equal to the difference of potential dV divided by the distance ds' from an equipotential surface measured along the line of force.

$$F = dV/ds'$$

In constructing an electric field we make use of the fact that the lines of force and the equipotential lines are an orthogonal system. For any arrangement of conductors in a homogeneous medium the approximate form of the field may be drawn by guess. The method used here is only applicable in checking up and correcting the approximately drawn field.

Measurements are made from the approximate drawing for the ds' distances between any two equipotential lines, one of which is used as a base line. Assuming that $dV = 1$ between these two equipotential surfaces, the force equation then becomes

$$F = 1/ds'$$

For each point along the equipotential line find F by using the reciprocal values of ds', and plot the *Force*-curve as shown in Fig. 1.

If now we integrate the area under the *Force*-curve, for example from o to the line AB, by means of a planimeter or other device, we get a value B for the definite potential integral,

$$V = \int_0^s F ds$$

Integrating to another point C on the *Force*-curve a value D on the *potential*-curve is then obtained. We may proceed in this manner for all points along the equipotential line as far as is desirable.

Projecting lines back to the *Potential*-axis from the points B, D, etc., increments dV are cut off which give the difference of potential between the base line and the approximate equipotential line for every point considered. If the increments dV

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* Communicated by Prof. Jakob Kunz.

are equal, then the drawn curve is truly an equipotential line and the drawing is correct.

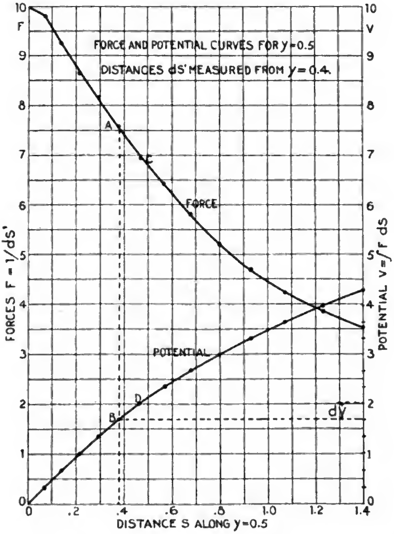
The whole field may be checked in this manner and corrected to exactness. This method, when properly used, will give the true conformation of the electric field which will, in fact, be the solution of Laplace's equation for the particular case in hand.

$$\Delta V = 0$$

EXAMPLE.

The field has been constructed and checked for the case of a thin wire strung through the centre of a circular hole in a thin infinite plane. The field is shown in two dimensions in Fig. 2, the *iV*-axis representing the central wire and the *U*-axis from ± 1 to ∞ representing the thin plate. The field is symmetrical and may be represented in three-dimensional space by rotating the diagram about the *iV*-axis.

FIG. 1.



This field is in reality an orthogonal system of confocal ellipses and hyperbolas and may be represented by the equation,

$$w = \cos h\ z = U + iV$$

where z is the complex number,

$$z = x + iy$$

This equation is easily solved for the functions U and V,

$$W = \cos h\ (x + iy)$$

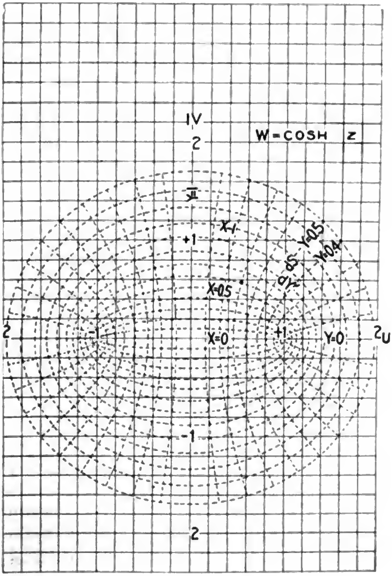
$$W = \frac{e^z + e^{-z}}{2} = \frac{e^{(x+iy)} + e^{-(x+iy)}}{2}$$

$$W = 1/2\ e^x(\cos y + i \sin y) + 1/2e^{-x}(\cos y - i \sin y)$$

$$W = \cos y \frac{e^x + e^{-x}}{2} + i \sin y \frac{e^x - e^{-x}}{2}$$

$$W = \cos y \cos h\ x + i \sin y \sin h\ x = U + iV.$$

FIG. 2.



Which gives

$$U = \cos y \cos h\, x.$$
$$V = \sin y \sin h\, x.$$

and

Squaring the equations and subtracting gives

$$U^2/\cos^2 y - V^2/\sin^2 y = 1,$$

which is the equation for a family of confocal hyperbolas. Giving different values to y, we find the family of hyperbolas having their foci at ± 1.

Adding the squared equations gives

$$U^2/\cos^2 h\, x + V^2/\sin^2 h\, x = 1,$$

the equation for a family of confocal ellipses with foci at ± 1, the same foci as for the hyperbolas.

To illustrate the method, we will take the equipotential line $y = 0.4$ as the base line and measure the distances ds' to the equipotential line $y = 0.5$, along the lines of force which are represented by the different values of x. These distances are recorded in the second column of the table.

Assuming $dV = 1$, the forces $F = 1/ds'$ are found and recorded in the third column.

Now, beginning from $x = 0$, the ds distances between consecutive lines of force are measured along $y = 0.5$ and recorded as in column four.

Column five gives the distance s to any point on $y = 0.5$ from the starting point on $x = 0$.

The forces for each point on the line $y = 0.5$ are now plotted as in Fig. 1.

Integrations under the *Force*-curve are performed and the results recorded as in the sixth column, from which values the *Potential*-curve is plotted and projections made to the *Potential*-axis.

The potential differences dV as found along each line of force are approximately of equal values, as may be seen in the last column, which means that the line $y = 0.5$ is an equipotential line.

In this manner it is possible to check over the entire field and to change the rough approximate drawing to the correct form.

The drawing in Fig. 2, representable by $w = \cosh z$, is a true electric field where the lines represented by the y values are the equipotential lines and the lines represented by the values of x are the lines of force.

SUMMARY.

1. A graphical method is explained which permits the construction of any electric field, or the solution of Laplace's differential equation.

2. As an example the field for a thin wire strung through a circular hole in an infinite plane is given.

3. This field is representable by $w = \cosh z$.

In conclusion, I wish to thank Dr. J. Kunz for a suggestion regarding the given graphical solution of Laplace's differential equation.

TABLE.

Potential Difference Between $y = 0.4$ *and* $y = 0.5$.

ONx	ds'	$F = 1/ds'$	ds	S	$\int_0^S F\, ds = V$	dV
0.0	0.100	10.000	0.000	0.000	0.00	0.00
0.1	0.102	9.800	0.068	0.068	0.33	0.33
0.2	0.108	9.250	0.092	0.140	0.67	0.34
0.3	0.116	8.625	0.076	0.216	1.01	0.34
0.4	0.120	8.320	0.078	0.294	1.34	0.33
0.5	0.132	7.575	0.084	0.378	1.68	0.34
0.6	0.144	6.950	0.092	0.470	2.02	0.34
0.7	0.156	6.410	0.100	0.570	2.34	0.32
0.8	0.172	5.810	0.110	0.680	2.66	0.32
0.9	0.192	5.210	0.118	0.798	2.99	0.33
1.0	0.212	4.715	0.130	0.928	3.31	0.32
1.1	0.236	4.240	0.142	1.070	3.64	0.33
1.2	0.260	3.850	0.160	1.230	3.96	0.32
1.3	0.284	3.525	0.172	1.402	4.28	0.32

UNIVERSITY OF ILLINOIS,
June, 1917.

The Use of Windmills in Irrigation in the Semi-arid West. P. E. FULLER. (*U. S. Department of Agriculture,* Farmers' Bulletin 856.)—The feasibility of windmill irrigation depends much upon the head or height of water that must be lifted from the well, and it is scarcely practicable to use windmills for irrigation purposes if the water table or level is over 60 feet from the surface of the ground. Raising small quantities of water against a high head by such power is practicable for stock or domestic use; but the limited power of the ordinary mill is not sufficient to pump the large volumes needed for irrigation. As there is only a small percentage of time during which the wind attains a velocity favorable to the most economical mill load, the total quantity of water will be small unless a very large mill is used. Many mill manufacturers stipulate that their mills will perform certain work in an average velocity of 16 miles per hour during eight hours per day, but this is misleading and may result in an overestimate of the results expected. The average hourly velocity should not enter into the choice of a mill; the basis should be the time during which the wind maintains certain rates per hour.

It might be supposed, naturally, that if the load is too small for the mill, the small amount of water pumped per stroke would be compensated by the greater number of strokes made by the mill. While this is true to some extent, it should be remembered that there is but one economical or efficient speed for each wind velocity. If the load cannot be varied with each change of wind velocity, the best economy will be obtained by adopting a cylinder which will load the mill at the most economical point during the greatest time possible. Several devices have been invented for adjusting the load to the wind velocity. Some are operated by hand, but this mode of operation is impracticable. One regulator lengthens the stroke of the pump automatically as the wind increases in velocity and shortens the length of the stroke as the wind velocity decreases. The average gain in water pumped through the application of the stroke regulator was found in a test to be approximately 30 per cent. This regulator has demonstrated its applicability to windmill work, and if by certain changes in mechanical construction its durability can be assured, it will prove a valuable device in windmill operation.

The practice of some manufacturers of decreasing first cost by the use of inferior metal of inadequate section in windmill towers is to be regretted. A tower should have sufficient strength to safely withstand the highest wind velocities, and the slight additional cost entailed is amply justified. Wooden towers are good where clear timber is available at a reasonable cost, but unless they are substantially built and kept painted their life is short. In some localities, however, wooden towers have made an excellent record for long life. In the vicinity of Stockton, Calif., some old wooden mills have been in service 30 years. The height of the tower has much to do with the success of a mill. It should never be located where the wind is obstructed in its free access to the mill, and it should be high enough above the ground to realize the full effect of the wind. Ordinarily 40 feet will give excellent results, though in some places the wheel may be set only a few feet above the ground. If more than one mill is used, the location with respect to each other should be given consideration, for if placed in line with the prevailing wind one will obstruct the wind considerably, even if placed at such distances apart as 500 feet.

NOTES FROM THE U. S. BUREAU OF STANDARDS.*

GAS-MANTLE LIGHTING CONDITIONS IN TEN LARGE CITIES IN THE UNITED STATES.[1]

[ABSTRACT.]

FROM a careful inspection of about 4500 gas-mantle lamps in service in ten cities a summary of the condition of mantles, glassware, pilot light, and other particulars was made in order to determine to what extent the customer benefited through periodic maintenance service. By those observations it is found that a lamp not on regular maintenance is likely to be defective five and a half times as frequently as a lamp which is regularly maintained. Also, it is shown that, on the average, one in three of the lamps on regular maintenance was not in good condition, whereas the defects noted in the lamps not so maintained average more than one for every lamp.

THE DETERMINATION OF ABSOLUTE VISCOSITY BY SHORT-TUBE VISCOSIMETERS.[2]

[ABSTRACT.]

THE Engler and the Saybolt Universal viscosimeters, which are the instruments usually employed in the oil trade, have such short outlet tubes that the equation for the flow through long capillary tubes is not applicable without correction factors. The literature has been carefully reviewed and further experimental work has been done. The conclusion is reached that water is not a suitable liquid for use in finding the relation between viscosity and time of discharge for short-tube viscosimeters, and that Ubbelohde's equation, and all others based upon it, are seriously in error.

EFFECTS OF HEAT ON CELLULOID AND SIMILAR MATERIALS.[3]

[ABSTRACT.]

A STUDY of the behavior of celluloid and of pyroxylin plastics in general, when heated to different temperatures, com-

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* Communicated by the Director.

[1] Technologic Paper No. 99.

[2] Technologic Paper No. 100.

[3] Technologic Paper No. 98.

mences in the neighborhood of 100° C., and above this temperature the heat of decomposition may raise the temperature of the mass to the ignition point. At 170° C. decomposition takes place with explosive violence. Pyroxylin plastics can be ignited by momentary contact with bodies having a temperature of 430° C. and upward. The rate of combustion is five to ten times that of poplar, pine or paper under the same conditions. The vapors evolved during the decomposition of pyroxylin are poisonous and extremely combustible, and may be ignited by the heat of decomposition.

PUBLIC UTILITY SERVICE STANDARDS OF QUALITY AND SAFETY.[1]

[ABSTRACT.]

A BRIEF outline of the public service activities of the Bureau, together with lists of the publications bearing on the various subjects which are issued by the Bureau. The subheadings giving the public service activities are: Standards for Electric Service, Standards for Gas Service, Standard Methods of Gas Testing, National Electric Safety Code, Electrolysis Mitigation, Further Activities.

ANNUAL REPORT OF DIRECTOR.

SCIENTIFIC work of unusual volume and interest is described in the annual report of the Director of the Bureau of Standards, just issued. The work ranges from the testing of clinical thermometers to the publication of national electrical and gas codes. Since the war began, all branches of this scientific bureau have been conducting researches on technical problems of military application. The regular work, however, has not been overlooked. In fact, the variety and importance of the results obtained during the year in its scientific and technical researches are of unusual interest.

The standardiaztion work has comprised the making of 155,000 tests of weights, measures, measuring instruments, and materials; the promulgation of a new standard screen scale for unifying the sizes of industrial sieves; the new gauge standards laboratory for testing munitions gauges; investigation of the accuracy of leather measuring instruments; standardizing blood-counting apparatus, including new specifications based on researches on the errors of such apparatus; the standardization of master scales in 21 states and of the master scales of the American Railway Association; extension of the work on altitude measuring instruments to include all varieties of aviation instruments; and a large number of special researches in physics of materials.

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[1] Circular No. 68.

The report describes much interesting work on standards for electrical measurements; radio researches; practical tests of the Bureau's radio fog-signalling system; radio direction finder; magnetic system of testing steels to ascertain quality for tool making, rail making, ball bearings, and the like; standardization of radium and radio-active preparations, including radium luminous paints for watch dials, and the dials of aviation instruments; inauguration of the work on X-ray standardization; improved methods of light measurement; standard practice codes issued as national standards for electric service and for gas service; work on standards for street lighting service, and on standards for telephone service; investigation of gas-mantle conditions in the leading cities; and the important work of safeguarding underground structures from the damage caused by stray electric currents.

The optical work of the Bureau is of special interest and includes the precise measurement of wave-lengths of various colors for use as standards in optical work, red and infra-red photography as applied to the photography of the spectra of laboratory materials, and of the stars and the sun; optical methods of finding impurities in materials; sugar determination by optical means; determination of sugar content of molasses; industrial standards of color for certain industrial materials; standardization of optical apparatus, such as camera lenses, field-glasses, range finders, and similar equipment; analysis of radiation with respect to energy distribution.

The chemical work of the Bureau included the development of new methods of analyzing steel and other materials; study of platinum purity; coöperation upon military researches involving chemistry, such as the preparation of special gases, combustion gas detectors; and chemical researches and materials testing in great variety and quantity for the Government.

The Bureau's technologic work comprises a wide range of researches into the special technologies of the metals, cement, clay, clay products, lime, stucco, paints, roofing materials, and miscellaneous materials, such as paper, textiles, rubber, leather, glass, and the like. The results are published by the Bureau in a series of about 20 technologic papers issued during the year.

The regular growth of the Bureau and its special expansion on account of war work have resulted in the construction of several new laboratories and an increase in the staff of about sixty per cent.

To all interested in the applications of science to industry and to warfare the annual report of the Bureau of Standards will be of particular interest.

Waterwheel Reversed to Absorb Energy During Test. Anon. (*Engineering News–Record,* vol. 79, No. 22, p. 1023, November, 1917.)—The contract for the hydraulic equipment in the crosscut hydroelectric plant built for the U. S. Reclamation Service on the Salt River Reclamation Project in Arizona was let with a bonus or penalty dependent upon the efficiency obtained. A study and comparison of methods of conducting the test revealed the inadvisability of using the usual water rheostat methods of absorbing the load. With the consent of the waterwheel manufacturer it was therefore decided to connect the generator of the wheels under test with the generator of another unit in such a way that the latter could be run as a motor. Thus the load could be taken up by the jets from the nozzles, retarding the reverse rotation of the buckets.

The specifications provided that any one of the six units might be selected for the test. On bringing the machine selected for test to speed, the machine selected for load also came up to speed as a synchronous motor. The connections on the unit intended to supply the load were reversed, of course, so that when supplied with power from an external source its direction of rotation was opposite to normal. After some experiment it was decided to disconnect the governors and rely entirely on hand regulation. One penstock was used for supplying water to the unit under test and another for supplying water to the exciters and providing the load in the braking unit. With water through the nozzles of the unit operated as a synchronous motor, electric energy was absorbed in direct relation to the hydraulic energy developed by water passing through its nozzles. Therefore, as the nozzles were gradually opened on the unit under test, a relative additional quantity of water was admitted to the motor unit.

NOTES FROM THE RESEARCH LABORATORY, EASTMAN KODAK COMPANY.*

HIGH-TEMPERATURE DEVELOPMENT OF ROLL FILM, FILM PACKS, PLATES, AND PAPER.[1]

By **J. I. Crabtree.**

[ABSTRACT.]

ROLL film, film packs, and plates, whether new or date-expired, may be successfully developed under tropical conditions (up to 95° F.) by means of most developers, with the addition of 10 per cent. sodium sulphate and some potassium bromide in order to prevent fog, but much better with a special developer compounded with paraminophenol hydrochloride. Although it has been recommended to develop film in the tropics by hardening the same, either before or after development, by the addition of a hardener such as formalin, it is only possible to secure the best results by using a developer free from such addition agents. The formula for the developer is as follows:

Paraminophenol hydrochloride	7 grammes
Sodium sulphite (E. K. Co.)	50 grammes
Sodium carbonate (E. K. Co.)	50 grammes
Water to	1 litre

Rinse for only one or two seconds before placing in the fixing bath, otherwise the film is apt to soften in the rinse water.

The time of development with Eastman N. C. film at 95° F. for normal contrast is one and a half minutes, though the time of development may be doubled by the addition of 100 grammes of sodium sulphate (crystal) per litre of developer.

At temperatures up to 75° F. the regular acid fixing bath should be used, but at temperatures up to 85° F. the following chrome alum bath is necessary:

	Avoirdupois	Metric
Hypo	7 oz.	200 grammes
Sodium sulphite (E. K. Co.)	1 oz., 175 grains	40 grammes
Potassium chrome alum	2 oz., 350 grains	80 grammes
Acetic acid (glacial)	40 minims	2.5 c.c.
Water to	32 oz.	1 litre

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* Communicated by the Director.

[1] Communication No. 62 from the Research Laboratory of the Eastman Kodak Company, published in *British Journal of Photography,* 1917, p. 551.

Dissolve the sulphite and chrome alum together and add to the hypo solution, finally adding acetic acid.

At temperatures up to 95° F. the following formalin bath should be employed:

	Avoirdupois	Metric
Hypo	9 oz.	250 grammes
Sodium sulphite (E. K. Co.)	1 oz., 350 grains	50 grammes
Formalin (formaldehyde 40 per cent.)	4¼ oz.	125 c.c.
Water to	32 oz.	1 litre

First dissolve the hypo, then the sulphite, and finally add the formalin.

In order to eliminate the odor of the formalin, the bath should be enclosed in a covered tank if possible. The above baths keep well at the temperatures stated, so that for the professional and amateur finishing trade the special chrome alum bath is very suitable, while in special cases, such as expeditionary work, when very high temperatures may prevail, the formalin bath will give perfect results.

Film packs may be successfully treated in a tray in the same way as N. C. film, though so far it has not been possible to devise a method for using the Kodak film or film pack tanks at the temperatures named.

Although no difficulty is to be expected when developing gaslight and bromide papers at high temperatures, the use of a stop bath of 3 per cent. acetic acid and twice the usual amount of liquid hardener in the fixing bath is recommended.

NOTES FROM THE RESEARCH DIVISION, ELECTRICAL ENGINEERING DEPARTMENT, MASSACHUSETTS INSTITUTE OF TECHNOLOGY.*

APPARENT DIELECTRIC STRENGTH OF VARNISHED CAMBRIC.

In December, 1913, a paper by Mr. F. M. Farmer was read before the American Institute of Electrical Engineers in New York on "The Dielectric Strength of Thin Insulating Materials." A large number of experimental observations were recorded in the paper, on the apparent dielectric strength of thin sheets of varnished cambric, hard rubber, oil, and air, when tested between opposed parallel circular disk electrodes of various diameters. It was shown that in all cases the apparent dielectric strength diminished when the diameter of the disk electrodes was increased. With varnished cambric sheets the dielectric strength diminished 13.4 per cent. between 1.1 and 5.1 cm. of disk diameter.

It is generally accepted that, provided the tested dielectric sheet has a thickness not exceeding, say, five per cent. of the disk diameter, the electric field across the sheet is very nearly uniform. It might therefore be supposed that the area of the tested sheet would not affect the breakdown voltage, which, in a strictly uniform field, should be simply proportional to the thickness of the test sheet and independent of the area.

The only reason that was suggested in the discussion following the paper for the apparent diminution in breakdown voltage with area was a "weak-spot" theory. That is, it was supposed that a large disk would probably cover more accidental weak spots than a small disk, and so would be likely to invoke a lesser breakdown voltage. It is impossible to deny the validity of this argument, and yet it is not easy to assign a quantitative value to this diminution according to such a theory. Moreover, essentially the same phenomenon was presented with films of oil and air, fluid media in which weak spots are not supposed to occur.

The subject received attention in the M. I. T. laboratories during 1913-1914 in thesis work. Mr. L. H. Webber repeated and confirmed a number of the original observations in the Farmer paper. Again, in 1914–1915, Mr. G. Y. Fong repeated the tests, with sheet cambric previously immersed in oil. The diminution in rupturing voltage with disk diameter was then found to be distinctly less with oil-immersed cambric than with air-immersed cambric.

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* Communicated by the Director.

A complete series of dielectric strength tests was then carried on in the years 1915–1917 by Dr. R. J. Wiseman, under an appropriation from the American Telephone and Telegraph Company. A great variety of mechanical and electrical conditions were tried. The simplest arrangement arrived at was to support a test sheet of varnished cambric upon a fixed flat horizontal metallic disk electrode 10 cm. in diameter. The upper electrode was then laid on top of the test sheet so as to lie symmetrically over the lower fixed electrode. The breakdown voltage was supplied from a sine-wave alternator, through a 10-kva. step-up transformer. The voltage on the primary or low-tension side of the transformer was regulated, by varying the field excitation of the alternator, in such a manner that the secondary electromotive force impressed on the test sheet rose at the rate of approximately 1000 r.m.s. volts per second. The electrodes of the test sheet were connected directly to the secondary terminals of the transformer by relatively short copper wires. Intermediate water resistances were used, at first, in these tests; but they were afterward removed without appreciable effect. A specially calibrated voltmeter in a tertiary circuit of the transformer enabled the r.m.s. electromotive force applied to the test sheet to be noted at the moment when rupture occurred.

It was found that when the upper electrode was a single metallic disk, the r.m.s. breakdown voltage fell off 13.3 per cent., as the area of the upper disk was increased from 1.1 to 18 sq. cm.

When, however, the upper electrode was formed of a number of separate brass disks, each 1.13 sq. cm. area, all resting on the test sheet and each connected to a common terminal by a straight, fine copper wire 40 cm. long, there was only about 1 per cent. diminution in breakdown voltage when the number of the little upper disks was increased from 1 to 16, with a corresponding increase in total active area from 1.1 to 18.1 sq. cm.

It thus became evident that the diminution in apparent dielectric strength with increase in size of the disk electrodes did not depend upon the active electrode surface, but upon the way in which the electrode surface was put together. This test was checked with different observers and apparatus at the Electrical Testing Laboratories in New York.

It was further ascertained that when the multiple upper electrode disks were set together into a connecting brass backing or frame the diminution in breakdown voltage with increase of active area from 1.1 to 18.1 sq. cm. increased to about 15.4 per cent., or even more than with the original single brass disks.

Again, when the multiple upper electrode disks were set into a hard-rubber back frame and connected together by short, strong copper wires immediately above the rubber frame, the diminution of voltage was 10.8 per cent.; whereas, if the connection was made by fine, straight copper wires about 40 cm. long to a common terminal, the diminution fell to 5.8 per cent.

By the courtesy of Mr. Farmer, all of these tests were repeated at the New York laboratories and checked in substance, although the agreement as to diminution was not precise in detail.

No satisfactory demonstration has yet been obtained as to the reasons for the above-mentioned phenomena. They suggest, however, the possibility of the existence of very high-frequency electric oscillations superposed upon the voltage wave of the testing frequency, which was 60 cycles per second throughout. It is conceivable that when a high-potential alternating electromotive force is impressed upon the two disk electrodes, which form, with the interposed test sheet, a condenser, high-frequency disturbances may be set up between different parts of the condenser, considered as an oscillating system. If such high-frequency oscillations occurred, air pocketed between the surface of the varnished cambric and either electrode would be ionized, and the ions might actively bombard the dielectric in the destructive manner which Ryan and other high-frequency experimentalists have already demonstrated. When the disk electrodes are enlarged, the frequency of such parasitic free oscillations would be lowered, but their amplitude and energy would be increased. If, however, the electrode surface is broken up into elements connected together by relatively long, thin wires, such oscillations would be damped and hindered. Confirmatory experimental evidence will, of course, be necessary before such a theory of diminution in breakdown voltage with disk diameter can be reliable.

A more detailed description of the tests and apparatus appears in *Electrical World* for December 15, 1917, vol. 70, No. 24.

The Technic of Reading. L. LAURANCE, in *Institute Journal* (London). (*The Optical Journal and Review*, vol. 40, No. 24, p. 1530, December 6, 1917.)—When a person is reading, all that he can see clearly at any given moment is that amount of type whose image can be included in the true macula area. About 25 mm. is the length of print which can be read without movement of the eyes. Actually it is not so much; the angle of clear vision includes, at the usual reading distance, some one and a half words or perhaps two short ones. The eyes are converged for the reading distance as if the point of fixation were always on the median line, and the convergence is maintained as the eyes rotate right and left in order to read each word in each line of print, although at given moments the print is immediately opposite to one and the other eye.

The rotations of the eyes from left to right are not achieved by a continuously gliding movement, but by jerks and pauses. When the two eyes are turned to the left to fix the beginning of a line, the fixation point will be automatically a little to the right of the first letter; the first word or two having been read, the eyes are jerked over to the next external macular field, there being then a pause in order that it may be seen and mentally appreciated, and so successively until the whole line is read. The jerks are exceedingly rapid, but the pauses occupy a definite length of time, sufficiently great for the retinal image to be formed and communicated to the brain. The number of jerks and pauses varies with the length of the line, the number being, say, 5 to 8. The difficulty met with when reading very long words consists partly in the fact that more than a single pause is required to cover them visually.

The educated individual reads more rapidly than the uneducated because he does not need so many pauses to a line; he takes longer jerks and mentally fills in any letters or short words that he does not see clearly. The person of lower mentality must visualize every word, and indeed every letter, in order to grasp the meaning of what he reads. In fact, this occurs with educated persons also when reading matter with which they are unaccustomed. This natural failure to visualize every letter accounts for the fact that a misprint can be unnoticed by innumerable readers of a book or paper.

As a rule, there is not a great deal of vertical rotation in order to see letters, but, again, there is a marked difference between the trained and the untrained reader. The former views mainly the upper parts of the letters and mentally fills in the lower; the latter must see the whole of each letter and expend time in vertical eye movements in order to do this. It is a well-known fact that it is comparatively easy to read type of which the lower halves are covered, whereas it is very difficult to do so if the upper halves are hidden from view and the lower only exposed.

THE FRANKLIN INSTITUTE.

(Proceedings of the Stated Meeting held Wednesday, December 19, 1917.)

HALL OF THE FRANKLIN INSTITUTE,
PHILADELPHIA, December 19, 1917.

PRESIDENT DR. WALTON CLARK *in the Chair.*

Additions to membership since last report, 2.

Mr. Louis E. Levy, chairman *pro tem.* of the Committee on Science and the Arts, reported the condition of the work of the committee.

The following nominations were made for officers and managers to be voted for at the annual election to be held on January 16, 1918:

For President (to serve one year), Walton Clark.

For Vice-President (to serve three years), Louis E. Levy.

For Treasurer (to serve one year), Cyrus Borgner.

For Managers (to serve three years), Charles Day, Kern Dodge, Alfred W. Gibbs, George R. Henderson, George A. Hoadley, Isaac Norris, Jr., Lawrence T. Paul, James S. Rogers; (to serve two years) Gellert Alleman.

Mr. Louis E. Levy, on behalf of the Committee on Science and the Arts, then introduced Mr. Edward C. Baker, president of the International Money Machine Company, and representative of Mr. Thomas Bilyeu, who had been recommended for the award of the John Scott Legacy Medal and Premium for his inventions embodied in the International Money Machine. The President presented the medal and accompanying certificate to Mr. Baker, who thanked the Institute on behalf of Mr. Bilyeu for this recognition.

The paper of the evening, on "Military Highways," by Logan Waller Page, Director of the Office of Public Roads and Rural Engineering, U. S. Department of Agriculture, was presented by Mr. E. W. James, general inspector of the office. The location, control, and design of modern highways were given consideration, as well as the use and maintenance of these in the light of the great development of motor transport. The lessons taught by the military and economic development incident to the movement and supply of great bodies of troops on European battlefields were pointed out. Consideration was also given to the defensive value of highways properly correlated with the schemes of civil development now in operation among the several states.

After a brief discussion the thanks of the meeting were extended to the speaker.

Adjourned.

GEORGE A. HOADLEY,
Acting Secretary.

COMMITTEE ON SCIENCE AND THE ARTS.

(Abstract of Proceedings of the Stated Meeting held Wednesday, December 5, 1917.)

HALL OF THE FRANKLIN INSTITUTE,
PHILADELPHIA, December 5, 1917.

MR. CHARLES E. BONINE, *Chairman pro tem.*

The following report was presented for first reading:

No. 2703.—Sweetland Filter Cloth.

The following reports were presented for final action:

No. 2693.—Dressler Tunnel Kiln. Conrad d'Huc Dressler, of Great Marlow, England, recommended to the City of Philadelphia for the John Scott Legacy Medal and Premium.

No. 2705.—Levy Hæmocytometer. Recommended that the Edward Longstreth Medal of Merit be awarded to Max Levy, of Philadelphia, Pa.

GEORGE A. HOADLEY,
Acting Secretary.

SECTIONS.

Section of Physics and Chemistry.—A meeting of the Section was held in the Hall of the Institute on Thursday evening, December 6, 1917, at 8 o'clock, with Dr. George A. Hoadley in the chair. The minutes of the previous meeting were approved as read.

Henry Norris Russell, Ph.D., Professor of Astronomy in Princeton University, and director of its Observatory, delivered an illustrated lecture on "The Use of Photometric Methods in Astrophysics." The photometric methods used in astrophysical research were enumerated, and a description was given of the results obtained by the application of these methods in the study of the sun, moon, asteroids, planets, satellites, rings of Saturn, variable stars, eclipsing variables, nebulæ, star clusters, and the Milky Way.

The paper was discussed by Prof. Eric Doolittle and others. On motion of Dr. Herbert E. Ives, a vote of thanks was extended to Doctor Russell. The meeting then adjourned.

JOSEPH S. HEPBURN,
Secretary.

Mechanical and Engineering Section.—A joint meeting of the Section and the American Society of Mechanical Engineers was held in the Hall of the Institute on Tuesday evening, December 11, 1917, at 8 o'clock.

Dr. George A. Hoadley, acting secretary of the Institute, and Mr. L. F. Moody, chairman of the Philadelphia Section, American Society of Mechanical Engineers, presided jointly. Mr. Joseph A. Steinmetz, of Philadelphia, presented the paper of the evening, entitled "Offensive Against the Submarine."

The speaker described the various methods and devices in use for combatting the submarine, and gave consideration to many of the suggestions which have been made for defeating the operation of this naval menace. A historical *résumé* of the subject was also presented. A large number of lantern slides were shown.

After a brief discussion the thanks of the meeting were extended to Mr. Steinmetz.

Adjourned.

ALFRED RIGLING,
Acting Secretary.

MEMBERSHIP NOTES.

ELECTIONS TO MEMBERSHIP.

(*Stated Meeting, Board of Managers, December 12, 1917.*)

LIFE.

MR. HENRY WOODHOUSE, Editor, *Aerial Age* and *Flying*, Foster Building, Madison Avenue and Fortieth Street, New York City, N. Y.

ASSOCIATE.

MR. LEON C. BIBBER, Marine Engineer, P. O. Box 64, Portland, Maine.

CHANGES OF ADDRESS.

MAJOR GEORGE S. CRAMPTON, Director of Field Hospitals, Camp Hancock, Augusta, Ga.

LIEUT. J. G. DETWILER, 1237 Seltzer Street, Philadelphia, Pa.

MR. PENROSE R. HOOPES, 1015 South Farragut Terrace, Philadelphia, Pa.

LIEUT. CHESTER LICHTENBERG, General Engineer Depot, U. S. Army, 1438 U Street, N. W., Washington, D. C.

LIEUT. THOMAS S. MARTIN, 3D, 1913 I Street, N. W., Washington, D. C.

DR. G. H. MEEKER, The School of Medicine, University of Pennsylvania, Philadelphia, Pa.

MR. FRED J. MILLER, Box 27, Center Bridge, Pa.

MR. CHARLES PENROSE, care of Day & Zimmerman, 611 Chestnut Street, Philadelphia, Pa.

MR. OSCAR L. SCHEHL, 1631 Girard Avenue, Philadelphia, Pa.

MR. A. F. SHATTUCK, 615 Canon Drive, Beverly Hills, Calif.

MR. L. H. THULLEN, General Delivery, Greenport, N. Y.

LIBRARY NOTES.

PURCHASES.

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FRITSCH, J.—Manufacture of Chemical Manures. 1911.

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JACKSON, D. C., and MCGRATH, D. J.—Street Railway Fares: Their Relation to Length of Haul and Cost of Service. 1917.

LAWS, F. A.—Electrical Measurements. 1917.

MEYERS, G. J.—Steam Turbines; A Treatise Covering U. S. Naval Practice. 1917.

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PIERCE, CHARLES.—Meteorological Account of the Weather in Philadelphia from January, 1790, to January, 1847. 1847.

PRICE, W. B., and MEADE, R. K.—Technical Analysis of Brass and the Non-Ferrous Alloys. 1917.

SNOW, C. H.—Wood and Other Organic Structural Materials. 1917.

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Globe Machine and Stamping Company, The Globe Tumbling Book. Cleveland, Ohio, no date. (From the Company.)

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Technical Photography and its Use in Industrial and Commercial Organizations. J. H. GRAFF. (*The Journal of Industrial and Engineering Chemistry,* vol. 9, No. 11, p. 1053, November, 1917.)—Practically no active technical, industrial, or commercial organization is complete without a photographic equipment in one form or another. With the exception of very few large establishments that maintain a photographic department for the purpose of photographing salesmen's samples, etc., there was until recently no concern in which a photographic department was installed as a distinct unit of the business, whose function it is to serve all the other departments and the company as a whole. The author believes himself to be one of the first to establish such a department in a large corporation, and to-day that photographic department has become a necessity.

In a large project of this kind the manager should be not only a photographer in the fullest sense of the word, but should also have a technical education and an adequate knowledge of the business to be served. Besides an equipment for copying documents of various kinds and laboratory and field photography, there are many advantages in facilities for the production of color work and photomicrography in the commercial field. The cost of a complete equipment is considerable, but this can be installed and developed by degrees in cases where the magnitude of the business served does not warrant a large expenditure. Perhaps one of the greatest difficulties of conducting a project of this kind is that of securing a duly qualified manager, and the author hopes to see established some day the profession of "Photographical Engineer," embracing the necessary theoretical and practical training for the purpose.

CURRENT TOPICS.

Stellite as a Substitute for Platinum. E. HAYNES. (*Proceedings American Chemical Society,* September 10 to 13, through *The Journal of Industrial and Engineering Chemistry,* vol. 9, No. 10, p. 974, October, 1917.)—Owing to the great scarcity of platinum and its consequent high price, platinum substitutes have been eagerly sought, particularly within the last three or four years. From what has already been accomplished in this direction it is evident that no single metal or combination of metals will fully take the place of platinum. The alloy of gold with palladium affords a partial substitute for crucibles and dishes, and perhaps more nearly replaces platinum in this respect than anything yet offered. The price of this alloy, however, is comparatively high, though, bulk for bulk, it is only about half as costly as platinum. The alloy of nickel with chromium, the silicon-iron alloys, and pure quartz have also given satisfactory results for certain laboratory purposes.

The stellite alloys are not fixed or definite in their composition, but may be divided broadly into two classes: (1) those malleable at red heat, and (2) those that can be worked into the desired form only by casting. The malleable alloys are composed almost entirely of cobalt and chromium, and the proportion may vary from 10 to 50 per cent. of chromium, with a corresponding variation of the other constituent. These alloys are very hard and resist nitric acid almost perfectly, even when boiling, particularly if the chromium content is over 15 per cent. They forge with difficulty at temperatures varying from 750° to 1200°. They have been forged into table implements, cutlery, chemical apparatus, and jewelry.

The malleable alloys are all slowly attacked by either hydrochloric, sulfuric, or hydrofluoric acid, but are nearly immune to all chemical combinations, as well as to the fruit acids. As evaporating dishes made of this metal take a bright polish, and can be made of comparatively light section, they will prove suitable for evaporating many chemical salts to dryness, and particularly suitable for boiling the caustic alkalies. Substances may be evaporated to complete dryness in these vessels without danger of breakage, since the tensile strength of the alloy exceeds 100,000 pounds per square inch. The vessels retain their lustre under practically all chemical laboratory conditions. The alloy also gives most excellent results in the form of lamp stands, supporting rings, triangles, etc. They can be heated to full redness without the formation of scale, and subjected to temperatures up to 1200° C., and still retain considerable strength. In fact, the stellite alloys possess the highest "red hardness" of any of the alloys yet discovered.

In many cases stellite may be substituted to great advantage for platinum in jewelry. It is almost of the same color, possesses a higher lustre, and retains its lustre very much better than platinum, since it is so hard that it is not scratched or abraded by ordinary use. While not nearly so pliable as platinum, it can be worked into many forms in jewelry without special difficulty.

Iron-wire Transmissions for Rural Extensions. L. P. PERRY. (*Electric World*, vol. 70, No. 15, p. 713, October 13, 1917.)—Many sparsely settled communities are deprived of electric service because central station companies cannot afford to build the lines to serve them. In fact, from data which have been collected, some rural copper-wire lines built to the standard used in well-settled districts have been unprofitable to the operating companies because the revenue obtained did not even pay for the overhead charges on the investment. In such cases, or where service is required for only a short period of years and the wire must be subsequently taken down, companies have had to look for cheaper methods of construction. Iron-wire transmission has been tried extensively of late, the companies taking advantage of the lower cost of conductors and the higher tensile strength, which permits larger pole spacings and consequently smaller investment in poles and insulators.

Seeing the possibilities in the use of iron wire, but being confronted with a state law which compelled it to secure the approval of the State Public Service Commission before such construction could be adopted, the Central Connecticut Power and Light Company has taken up the subject with the commission and received permission to use iron wire for certain extensions. At the time the request was made several 2200-volt line extensions had been promised to customers along a 13,200-volt transmission line, it being the intention to put cross-arms on the existing pole lines to accommodate the proposed 2200-volt circuit. This construction has not yet been approved, however, presumably because it has not yet been ascertained whether the high-voltage wires might break and come in contact with the low-voltage wires beneath.

At the conferences which were held the commission was alarmed lest the proposed types of construction should be more dangerous to the public than the present standard. In support of the petition it was shown that No. 6 bare double-galvanized B. B. iron wire is about one size larger and very much stronger than the commonly used No. 6 B. & S. gauge weather-proof copper wire. Iron wire has the further advantage of not having to carry a load of weatherproof insulation. Weatherproof copper wire is usually soft or medium drawn and much weaker than hard-drawn copper or iron wire.

If weatherproof copper wire is pulled up taut during hot weather it will contract and become so taut in cold weather that the wire draws out to a slightly smaller diameter. In the winter, when it is loaded heavily with sleet and subjected to high wind pressures, the tension may become so great that it will lengthen and sag until the tension has been reduced. During the following summer, owing to the higher temperatures, the wires will sag still further. Iron wire supported on poles placed 250 feet apart to give 6-foot sags is much stronger and much more likely to retain its original length and position than copper wire, usually erected on more closely spaced poles.

In the opinion of the commission, there seemed to be no question as to the strength of galvanized-iron wire when first installed, but the liability to rusting was viewed with some alarm. The petitioner held that iron wire can rust considerably before its cross-section is reduced to the point where it would be seriously weakened. If a small iron telephone wire is safe for ten or twenty years, the larger wires proposed for transmission purposes will, of course, have a longer life, since the larger the diameter the less the relative surface exposed to rust compared with the weight. Furthermore, although practically all 600-volt trolley wires suspended over the heads of pedestrians in busy city streets are supported by stranded galvanized-iron wire, casualties due to the rusting away of these wires seldom occur. While the commission was apparently satisfied with the initial strength of the proposed iron wire, it demanded, in granting permission for its use, that the operating company use extra vigilance during the semi-annual line inspection.

Advisability of Higher Steam Pressures. J. T. FOSTER. (*Electric World*, vol. 70, No. 23, p. 1090, December 8, 1917.)—At the time the subject of higher steam pressures was first brought prominently before the engineering world in 1915 there seems to have been some doubt as to whether it would be practicable to attempt a gain in thermal efficiency by increasing pressures much above those now in use. Since that time, however, it appears that considerable thought has been given to the subject, and a number of prominent engineers have expressed the view that high pressures are not only feasible, but inevitable. Previous discussions have been confined to thermal efficiencies, but a consideration of water rates is of greater practical interest. Calculations from Goodenough's formulas, published in Bulletin 75 of the Engineering Experiment Station of the University of Illinois, show how thermal efficiencies and water rates vary at boiler temperatures of 500°, 600°, and 700° F. with a vacuum of 28½ inches at the exhaust. From these results the lowest water rate of 6.95 pounds was found to occur at a pressure of 1100 pounds absolute and at a temperature of 700° F.

Practical considerations seem to offer no insuperable difficulties. Engineers experienced in the design of boilers and turbines have expressed the view that, while a certain amount of re-design will be necessary, the changes in the case of 500-pound or 600-pound operating pressures are not radical, and that as soon as there is sufficient demand the work of developing high-pressure apparatus will be undertaken. No reasons appear why large gains should not be realized. The change from 200 pounds to 500 pounds and 600 pounds is no more revolutionary than the change which was made at the time standard practice raised the pressure from 80 pounds to 200 pounds or more. In view of the fact that the earlier change netted a gain of approximately 20 per cent., the expected gain in economy from the change to 500 pounds or 600 pounds does not seem excessive.

A New Method of Constructing Difficult Foundations. E. A. PRENTIS, JR. (*Engineering News-Record*, vol. 79, No. 23, p. 1061, December 6, 1917.)—During the construction of the subways in New York City, particularly in the skyscraper district of Manhattan, a great deal of underpinning has been done. From experience in carrying on this work, a new method of constructing foundations for new buildings has been developed. The method may be said to consist in underpinning the building during its erection, so that the construction of the foundation goes hand in hand with that of the building itself. It is evident that with such a method a great saving of time can be effected—where, for instance, caissons would be needed to carry the column loads and a spread foundation is out of the question.

In the new method the foundations are designed in the usual way as pile foundations. Steel shells for the piles are driven a small distance into the ground, from 5 to 10 feet, by means of a hammer, and are cleaned out and concreted. Wooden blocks 3 or 4 feet long are placed on top of the piles, and the space around the blocks and the tops of the piles is back-filled with carefully tamped earth. A reinforced concrete girder with the necessary grout pipes is then cast on the back-fill and posts, thus supplying a preliminary support for the column loads. The footing so constructed is ready for the beginning of the construction of the building. When the building has reached three or four stories—of perhaps twenty to be built—the second stage of the construction proceeds. The column by this time supports sufficient weight for jacking purposes. Each wooden post is then removed and the pile jacked until the desired reaction is obtained. The load is then transferred to two I-beam posts or their equivalent on each side of the jack, the jack removed, and the I-beams concreted in as well as space allows. Final contact is made by means of the grout pipes.

Wood Trusses Incased in Concrete. ANON. (*The Contract Record*, vol. 31, No. 48, p. 983, November 28, 1917.)—Casing timber roof trusses in cement to protect them against fire and acid fumes is a novel method employed recently in the buildings of a large oil refinery in Texas. Wood construction was adopted on account of the shortage of structural steel. After the trusses had been erected each member was wrapped with a single layer of light water-proof building paper, placed close against the surface and fastened with carpet tacks. The object of this covering is to prevent any bond between the concrete and the wood and to protect the latter from the moisture used in applying the concrete casing.

Sheets of expanded metal with ½-inch diamond mesh were then cut and shaped to fit the members and fastened by No. 12 nails and special chairs stamped from flat-steel strips. These chairs kept the expanded metal ⅝ inch from the surface, so that it would be embedded completely in the concrete. Guide strips were tacked along the edges of the members to obtain the proper thickness of casing and to act as striking boards for the corner lines. With the work thus prepared, a 1½-inch coating of cement mortar of "gun-crete" was applied with cement guns. These operated under an air-pressure of 35 pounds, supplied by two oil-driven compressors, each having a capacity of 250 cubic feet per minute. Before this coating had fully set, the guide strips were removed and the surfaces left with an even finish.

The roof covering consists of a 1½-inch monolithic slab, built in place. Over the trusses and purlins was stretched a sheet of wire-mesh reinforcing secured by nails and chairs as noted above. Light wood panels were then laid upon this, and the concrete for the under side of the roof slab was shot in place by the cement gun. After about 24 hours the wood panels were removed. The concrete surface was then cleaned with compressed air and water to secure good bonding for the top coating, which was placed in the same way. Finally a thin coating of hot asphalt paint was applied. This work was done by the Cement-Gun Construction Company, of Chicago.

Liquid Oxygen as an Explosive. ANON. (*Mining and Scientific Press,* vol. 115, No. 20, p. 705, November 17, 1917.)—Utilization of liquid oxygen to form an explosive in connection with carbonaceous material has been revived by Mr. George S. Rice, of the Bureau of Mines. It is proposed to erect an experimental plant under Government auspices, in coöperation with the producers of the liquefied gas, who have shown great interest in the project. In a recent discussion before a meeting of the Mining and Metallurgical Society of America, Mr. Rice stated that shortage of materials commonly used in making explosives had led the Germans to adopt liquid air for saturating cartridges of carbonaceous matter to be employed for blasting coal in the mines of Upper Silesia. It was claimed that the efficiency of this makeshift explosive was equivalent to dynamite at 12 cents per pound.

Mr. Rice is using a mixture of various carbonaceous substances placed in a cheesecloth container along with a detonator; the cartridge is then dipped into liquid oxygen, and, although the best grade of oxygen at present obtainable is composed of only 55 per cent. of that element, a strength equal to about three-fourths of that 40 per cent. dynamite is realized. The function of the oxygen, of course, is to completely and instantaneously oxidize the carbon, the suddenness of the effect being such as to bring it within the realm of detonation. A large amount of information regarding explosives made with liquid oxygen is available, as this subject was extensively investigated about 18 years ago by a distinguished chemist, Sir James Dewar, in England. An experimental plant for its manufacture was also under consideration, if not actually erected, at Boston by a subsidiary of the British corporation. The investigations then made indicated favorable possibilities for the oxygen explosive, though some difficulties were experienced. Financial troubles prevented Dewar from continuing his efforts to commercialize the invention.

An Automatic Hydroelectric Plant. ANON. (*Electrical World*, vol. 70, No. 22, p. 1042, December 1, 1917.)—A hydroelectric generating station which is entirely automatic in all of its operations has recently been placed in service by the Iowa Railway and Light Company on the Cedar River, only a few blocks from the business district of Cedar Rapids. The plant, which will have an ultimate capacity of 2000 kilowatts, operates in parallel with an extensive transmission system which already reaches practically across the State of Iowa, except for a 28-mile break near Marshalltown. There are no instruments in the hydroelectric plant, these being installed in the company's steam station, which is about 0.6 mile distant. Three groups of conductors—power cables, instrument cables, and control cables—connect the two plants; hence, while the hydroelectric station is self-controlled and entirely automatic, it is possible for the steam-plant operators to supervise the action of the waterwheels and generators.

Perhaps the most spectacular and surprising feature of the whole plant is the speed with which the station goes into service. It requires just 37 seconds from the time the first switch operates until the first generator is under full load. A somewhat formidable array of mechanism might be expected in a plant of this nature, but the contactors and switches are inclosed in cabinets and the buses and control wires are run through bus chambers beneath the floor, so that the interior of the station appears very simple. With this arrangement, and by making each generator and its circuits, except for excitation, an independent unit, every element of the wiring and control apparatus has been made readily accessible.

The excitation for each machine is maintained at a fixed value at all times, thus simplifying the excitation problem, eliminating the necessity of voltage regulators, making it possible to take advantage of the full capacity of the river, and at the same time improving the power factor of the system through the operation of underloaded, overexcited machines. No oil governors are used for any of the machines, the gates being operated by motors which are upon complete automatical control at the hydroelectric station or remotely controlled from the steam station.

Repairing Marine Engine Castings by Electric Welding. E. P. Jessop. (*Journal of the American Society of Naval Engineers*, vol. 29, No. 4, p. 639, November, 1917.)—Immediately upon the seizure of the interned German and Austrian vessels located in the port of New York, when war was declared, steps were taken by the Shipping Board to proceed with the repair of these vessels as rapidly as possible. Electric welding was adopted as the most expeditious method of repairing the engine castings. All told, the principle of electric welding has been applied to 15 ships in the port of New York. Of these, all are in commission and will probably be shortly ready for service.

In order to successfully weld with the electric arc it is necessary to have complete control of the current. The arc must be directed along the line of fracture to be welded. Welding must be done slowly, the metal being laid on layer by layer, and each layer must be caulked and peened to knock or chip out the metal that has oxidized or hardened. Cast iron is not welded to cast iron direct. Special alloy-steel wire is used to supply the welding metal. In welding two cast-iron edges together a layer of steel is welded to each, and then these steel layers are welded to each other. It is difficult to weld two cast-iron parts together, but it is comparatively easy to weld a steel piece to a cast-iron piece. The advantage of electric welding is that the work can be done without preheating the parts and without removing the parts from the ship, provided the electric arc can be properly directed along the fracture.

It is notable that in all the work done by electric welding there has never been a failure, and this is particularly remarkable when it is considered that almost every conceivable kind of a patch was made and that the operations were on a more extensive scale than ever before attempted. The writer believes that this is the first work of its kind of any moment to be attempted in marine engineering, and that the scrapping of cast-iron parts of machinery is entirely unnecessary and will very soon be a thing of the past. In every case in which this method was used the repaired part was quite as strong as before the damage was done, and in most cases stronger.

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OCCLUDED GASES IN FERROUS ALLOYS.*

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PART I.—HISTORICAL.

ALL chemists are familiar with the epoch-making discoveries of Thomas Graham, the distinguished Scottish chemist. He is probably best known in consequence of his classical researches on the phosphoric acids and on the diffusion of gases and liquids. Having succeeded Sir John Herschel as Master of the English Mint, he proved to be an able administrator. He was also distinguished as a metallurgist, and in 1866 made the first published contribution on what we to-day term "occluded gases."[1] Previous to this time Sir Henry Bessemer[2] observed that the violent bubbling in molten steel during the cooling of the metal was due to the evolution of large quantities of carbon monoxide. Graham, however, was not aware of the importance of this observation. His work was suggested by an article published by

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* Presented at the stated meeting of the Institute, held Wednesday, October 17, 1917.

[1] *Proc. Roy. Soc.*, **15**, 1866–67, pp. 502–503.

[2] *Jour. Iron and Steel Inst.*, 1881, **1**, pp. 197–199.

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Deville and Troost[3] (1863) on "The Diffusion of Hydrogen Through Iron." Their results are summarized as follows:

"There may be imagined as existent in metals a new kind of porosity, the minuteness of which far exceeds that of charcoal and earthenware. This porosity is a physical phenomenon brought about by heat through an enlargement of the interstices between molecules. Although it is supposed to be a property of all metals, iron and platinum, at low temperatures, do not possess a porosity sufficient to permit of the diffusion of gases through them."

Graham concluded that if hydrogen possessed the property of diffusing through iron, it was more than likely that a certain amount of hydrogen would be absorbed by the iron during diffusion. The gas so absorbed he designated as "occluded" gas, and this term has since come into general use as being applicable to all gases so held. In his first experiment Graham used a piece of meteoric iron, weighing 43.2 grammes. After thoroughly cleaning the sample by washing it in a solution of hot potassium hydrate and subsequently in hot water, he dried it and placed it in a porcelain tube connected to a Sprengel mercury vacuum pump. The tube was then heated to redness, by means of a gas flame, and the quantity of gas which was evolved was measured at various periods. The results obtained were:

Time in minutes	Volume in cubic centimetres
35	5.38
Next 100	9.52
Last 20	1.63
Total 155	Total 16.53

The first portion of gas was burned and gave a flame similar to that of hydrogen. Analysis of the second portion showed it to have the following composition:

	Per Cent.
Hydrogen	85.65
Carbon monoxide	4.46
Nitrogen	9.86

From these data, and the specific gravity of the sample, it was calculated that one volume of iron evolved 2.85 volumes of gas.

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[3] *Compt. rend.*, **57**, 1863, pp. 965–967.

The only conclusion which Graham drew from the above results was that the atmosphere through which the meteor had passed consisted largely of hydrogen. Recent investigations seem to indicate that the atmosphere surrounding the earth to a height of from seventy-five to one hundred miles contains large amounts of hydrogen. The following table illustrates the supposed hydrogen content of the earth's atmosphere at various altitudes:

Height in kilometres	Per cent. hydrogen
140	99.15
130	99.00
120	98.74
110	98.10
100	95.58
90	88.28
80	64.70
70	32.61
60	10.68
50	2.76
40	0.67
30	0.16
20	0.04
15	0.02
11	0.01
5	0.01
0	0.01

REFERENCES ON DISTRIBUTION OF HYDROGEN IN THE ATMOSPHERE.

Ferrel: "Recent Advances in Meteorology," 1886, p. 37.
Hahn: "Lehrbuch der Meteorology," 1906, pp. 5–8.
v. dem Borne: *Physik. Zeitschr.*, 11 (1910), 11, p. 483.
W. J. Humphreys: *Bull. Mount Weather Obs.*, 1909, pp. 66–69.
JOURNAL OF THE FRANKLIN INSTITUTE, September, 1917, p. 388.

A. Wagener[4] gives a supplementary table, which differs from the above only in that these latter observations were carried out at higher altitudes. It is interesting to note that the figures thus obtained show a decrease in the hydrogen content of the atmosphere at altitudes over 150 kilometres. This, however, does not detract from the importance of these observations with reference to the subject in question, for, from a consideration of these results, it follows that the meteor probably acquired its hydrogen after passing from the ether into the atmosphere of the earth.

Graham's interest was considerably aroused by the results of his work on meteoric iron, and he sought to determine whether other ferrous materials were capable of absorbing gases. Employing the same apparatus and methods detailed in his first investigation, he heated 23.5 grammes of horseshoe nails. The amounts of gas produced and the analysis of the same are given in tabular form.

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[4] A. Wagener: *Z. Anorg. Chem.*, 75, 1912, pp. 107–131.

Time in Minutes	Volume in c. c.	Per cent. Hydrogen	Per cent. Carbon Monoxide	Per cent. Carbon Dioxide	Per cent. Nitrogen
First 150	5.40	35.0	50.3	7.7	7.0
Next ... 120	2.58	21.0	58.0	0.0	21.0
Total . 270	7.98				

It was calculated that one volume of metal yielded 2.66 volumes of gas.

While not directly connected with the subject outlined, we must refer to one of Graham's most interesting experiments. He made a palladium wire cathode in an acidulated solution. The palladium absorbed the H which migrated to it, and the wire, which originally had a length of 609.58 mm., attained a length of 619.34 mm.; in other words, the occlusion of H increased the length of this wire 9.77 mm.

Upon heating this palladium wire in a vacuum its length decreased to 600.18 mm., or 9.4 mm. less than its original length before it was made cathode.

Graham[5] next conducted a number of experiments investigating the amounts of hydrogen and carbon monoxide absorbed by palladium, platinum, gold, silver, antimony, and iron. His method consisted in (1) heating the metal in a vacuum in order to drive off the gas originally present; (2) then saturating the metal with hydrogen or carbon monoxide; (3) allowing it to cool, and (4) finally heating it again to determine the amount of gas evolved.

In performing these experiments no difficulty was experienced in obtaining satisfactory results except in the case of iron, from which it was found to be practically impossible to set free all of the gas originally occluded. Graham made no records of definite temperatures attained, merely stating that the porcelain tubes in which the determinations were made were heated to redness. In subsequent experiments Graham heated iron wire having a diameter of 0.4 mm. In a series of three experiments he was unable to remove all of the occluded gases from the wire.

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[5] *Proc. Roy. Soc.*, **16**, 1867–1868, pp. 422–427, and *Jour. of the Chem. Soc.*, **20**, 1867, pp. 257–292.

In his first experiment on wire he used 46 grammes of the wire mentioned. This, when subjected to several periods of heating, yielded, for each volume of iron, 7.94 volumes of gas, and the evolution had not ceased when the records given below were completed.

RESULTS OF EXPERIMENT No. 1

	Time in Minutes	Volume in c. c.	Per cent. Carbon Dioxide	Per cent. Carbon Monoxide
First	15	15.60	22.4	
Next	15	7.17	7.2	
Next	30	10.40		66.0
Next	30	8.16	1.4	
Last	30	5.52	0.5	
Total	120	46.85	31.5	66.0

In the second test a glass tube was employed, as Graham was in doubt as to whether the porcelain tube before employed was free from porosity. Thirty-five grammes of iron, on being heated for one hour, evolved 29.8 cubic centimetres of gas, of which 4.44 cubic centimetres was carbon dioxide, and the remainder mostly carbon monoxide, with traces of hydrogen and methane. One volume of iron yielded 7.27 volumes of gas.

In the third experiment 39 grammes of wire evolved, in seven hours, 63.10 cubic centimetres of gas, or one volume of iron produced 12.55 volumes of gas.

The iron left in the glass tube was then saturated with hydrogen and it was found that 0.42 volume was absorbed. On treatment with carbon monoxide one volume of the metal took up 4.15 volumes of that gas.

As a further experiment a piece of soft iron was allowed to remain in dilute acid for a time. As a result of this treatment 0.57 volume of hydrogen was occluded in the metal. In commenting on the results of these three experiments Graham advanced the theory that hydrides of iron were formed, and he considers it improbable that such large quantities of hydrogen could have been held in the gaseous state.

Simultaneously with the researches of Graham in England, Cailletet,[6] in France, was making observations on the gases evolved from iron during fusion. Employing two different samples of iron, he obtained gases of the following composition:

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[6] *Compt. rend.*, 61, 1865, pp. 850–852.

Gas	Sample No. 1 Per cent.	Sample No. 2 Per cent.
Hydrogen	33.7	38.6
Nitrogen	57.9	49.2
Carbon monoxide	8.4	12.2

Cailletet, however, was unable to duplicate his results, and discontinued the investigation.

Troost and Hautefeuille,[7] some years late, observed that when metals were heated and then allowed to cool, bubbles often appeared on the surfaces. They concluded that these bubbles were formed by gases which dissolved at high temperatures, and which were forced out of solution on cooling. In support of this theory of Troost and Hautefeuille, cast iron was heated in an atmosphere of hydrogen. Although at first no disturbance was noticed, when the pressure was suddenly lowered the evolution of gas was evident by the appearance of numerous bubbles. When allowed to cool and solidify, the surface of the iron was found to be very rough. It was thought likely, however, from comments previously made by Graham and by Cailletet, that certain amounts of gases were occluded at ordinary temperatures. In a series of experiments attempting to liberate the occluded gas, the investigators proceeded as follows:

A block of iron weighing 500 grammes was heated, in an evacuated porcelain tube, at 800° C. for 134 hours, and saturated, first, with hydrogen for 48 hours, and finally with carbon monoxide for 166 hours. After saturation the metal was reheated in order to determine how much of the gases had been absorbed. The accompanying tables give the results of these procedures:

EXPERIMENT NO. 1.—*Cast Iron*

Gas	Originally present		After saturation			
			In hydrogen		In carbon monoxide	
	Cubic centimetres	Per cent.	Cubic centimetres	Per cent.	Cubic centimetres	Per cent.
Carbon dioxide....	0.6	3.59	0.0	0.00	0.0	0.00
Carbon monoxide..	2.8	16.76	1.1	2.36	14.7	86.98
Hydrogen.........	12.3	74.07	44.0	94.42	1.5	8.87
Nitrogen..........	1.0	5.58	1.5	3.22	0.7	4.15
Total..........	16.7	100.00	46.6	100.00	16.9	100.00

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[7] *Compt. rend.*, **76**, 1873 pp. 482–485, 562–566, and *Annal. de Chem. et de Phys.*, **7**, 1876, pp. 155–177.

EXPERIMENT NO. 2.—*Steel.*

Gas	Originally present		After saturation			
			In hydrogen		In carbon monoxide	
	Cubic centimetres	Per cent.	Cubic centimetres	Per cent.	Cubic centimetres	Per cent.
Carbon dioxide....	.05	2.27	0.0	00.00	00.00	00.00
Carbon monoxide..	1.40	63.65	.9	11.53	2.0	62.5
Hydrogen.........	.50	22.72	6.4	82.05	.8	25.0
Nitrogen..........	.25	11.36	.5	6.42	.4	12.4
Total..........	2.20	100.00	7.8	100.00	3.2	99.9

EXPERIMENT NO. 3.—*Wrought Iron*

Gas	Originally present		After saturation			
			In hydrogen		In carbon monoxide	
	Cubic centimetres	Per cent.	Cubic centimetres	Per cent.	Cubic centimetres	Per cent.
Carbon dioxide....	2.2	11.89	0.0	00.00	00.00	00.00
Carbon monoxide..	10.8	58.38	.6	4.31	13.7	97.85
Hydrogen.........	4.4	23.78	10.0	71.94	.2	1.43
Nitrogen..........	1.1	5.95	3.3	13.75	.1	.72
Total..........	18.5	100.00	13.9	100.00	14.00	100.00

It is to be noted that in all three cases the carbon dioxide originally present is missing from the results of analyses made after the second heat. This shows one of two things: either that the carbon dioxide was completely driven off during the first heat, or that the part remaining was decomposed to carbon monoxide and oxygen. Since, however, Troost and Hautefeuille do not describe their analytical methods, we do not know whether any attempts were made to determine the oxygen content of the gas, and therefore cannot say with certainty which of the above explanations accounts for the disappearance of the carbon dioxide.

As to the order in which the gases were driven from the metal, Troost and Hautefeuille expressed the opinion that the oxides of carbon came off first, hydrogen showing a stronger affinity for the iron. The large volume of the test piece used prevented their determining whether all the gas had been driven off.

From the results of their work Troost and Hautefeuille arrived at several conclusions, which may be summarized as follows:

1. Whenever iron is held in a molten condition in contact with silica and silicates, carbon monoxide is produced by the action of iron carbide on the silica and silicates.

2. Molten iron dissolves appreciable quantities of hydrogen, but this amount is dependent on the impurities present, for silicon and phosphorus greatly diminish, while manganese greatly increases the quantity of hydrogen absorbed.

3. Carbon monoxide is much less soluble in iron than is hydrogen, and is rendered even less soluble by the presence of manganese.

4. Cast iron on solidification has been found to contain gases which may be expelled by heating the metal to 800° C.

5. Steel dissolves considerably less carbon monoxide and more hydrogen than does cast iron.

6. Soft iron, on the other hand, dissolves appreciably more carbon monoxide, which it likewise retains more tenaciously.

Upon continuing to follow in historical sequence the experiments conducted on the subject of occluded gases, it is found that John Parry[8] published the next series of investigations. In making his determinations Parry used three different kinds of tubes:

"1. One porcelain tube was enclosed within another, the intervening space being filled with a mixture of fire-clay and blast-furnace slag. Upon heating the empty tube for 48 hours under a vacuum there was evolved only 1 to 1.5 c.c. of gas, consisting mostly of air.

"2. A porcelain tube was painted with water-glass and rolled in finely powdered aluminous iron ore until uniformly coated.

"3. A glass tube enclosing a white clay tube with clay moulded over withstood a heat of about 1000° C. This latter type of tube was finally selected as being best adapted to the work for which it was intended."

The results of Parry's first series of experiments are summarized in the table on page 9.

All experiments at higher temperatures were unsatisfactory as the tubes melted. It was observed that the gas evolved at the lowest red heat consisted almost entirely of hydrogen, and that when the temperature was raised the percentage of carbon monoxide increased.

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[8] *Jour. Iron and Steel Inst.*, 1872, **2**, pp. 238–247; 1873, **1**, p. 430; 1874, **1**, pp. 92–102; 1881, **1**, pp. 183–194.

COMPOSITION OF GAS.

Material	Gas evolved per cubic centimetre of metal	Carbon dioxide	Carbon monoxide	Hydrogen	Nitrogen	Total
50 g. of Spiegeleisen (heated for 3 hours)	2 c.c.	0.942	17.87	81.105	.....	99.917
50 g. of common white pig iron (heated for 6.5 hours)	2 c.c.	6.80	2.32	84.00	6.88	100.00
37 g. of good wrought iron (heated for 2 hours)	2 c.c.	9.92	34.26	54.10	1.718	99.998
4.75 g. of gray pig iron (heated for 2 hours)	2.1 c.c.	1.6	5.2	89.7	3.25	99.75
10 g. of soft steel (heated for 2 hours)	13 c.c.	16.55	24.352	52.61	6.488	100.00

Parry repeated some of the experiments conducted by Graham on saturating iron with hydrogen and carbon monoxide. With carbon monoxide he obtained results which coincided almost exactly with those of Graham; but with hydrogen he got figures much higher than Graham's. Parry found that one volume of iron would absorb 4½ volumes of carbon monoxide and from 20 to 22 volumes of hydrogen. There was a very distinctive feature about the procedure used by Parry in these determinations. He measured the gas which was absorbed by the iron, whereas Graham had measured the gas indirectly by determining the volume evolved on heating the metal a second time.

In Table I, page 170, are tabulated a number of Parry's results obtained in a later series of investigations, in which he heated gray pig iron in a vacuum. From these data Parry concluded that the carbon monoxide was not present as such in the iron, but was the result of a chemical reaction between the porcelain tube and the carbon compound of the metal. This conclusion was based on the fact that when certain of the test samples were wrapped in platinum Parry got results much lower than when the samples were allowed to remain in contact with the tube.

In the second experiment a sample of gray pig iron evolved 58 volumes of hydrogen, while the same metal, when tested as previously described, was found to have taken up only 22 volumes. Parry was at a loss to account for this discrepancy.

About seven years after he had obtained the results recorded

TABLE I.

Gases Evolved from Gray Pig Iron Heated in Vacuo—Parry.

Sp. gr. of Fe—6.666	Hours	Gas c.c.	Composition, per cent.			1 vol. of Fe gives H_2 vols.	1 vol. of Fe gives CO vols.	Total volumes of H_2 +CO	Vols. per hr. H_2	Vols. per hr. CO	Remarks
			CO_2	CO	H_2						
10 G. red heat	7.5	36	3.49	30.37	66.13	16.72	7.28	24.0	2.23	.97	Kept warm one day, vacuum maintained.
10 G. again red heat	10	31	....	36.00	64.10	17.03	9.57	26.60	1.703	.957	
10 G. again red heat	9	19	....	43.80	55.90	7.09	9.51	12.60	.789	.611	Cooled to lowest red heat, 12 hours; good vacuo.
10 G. again red heat	10.5	21.5	....	46.20	52.78	7.70	6.60	14.3	.733	.638	
10 G. again red heat	14	22.7	....	38.20	61.34	9.34	5.77	15.1	.667	.412	
10 G. again red heat	9	18.7	....	38.20	61.20	7.67	4.73	12.4	.844	.527	
10 G. again white heat	16	34.1	....	68.10	31.89	7.21	15.39	22.6	.450	.962	Gas still evolved.
4½ G. red heat	19	11.11	2.00	30.00	66.16	11.55	4.95	16.5	.592	.278	
4½ G. white heat	9	23.35	....	57.10	43.90	14.80	19.70	34.5	1.646	2.186	
4½ G. white heat	9.5	16.0	....	52.00	47.00	23.43	25.37	48.8	1.340	1.460	Evolution slackens at white heat.
4½ G. white heat	8	17.0	....	.....	.....	.....	.....	.....	.....	.....	
4½ G. white heat	7	16.0	....	64.00	35.50	8.53	15.17	23.7	2.180	1.210	
Total from 10 G.	76	133	....	.....	.....	72.76	54.84	127.6	.....	.....	Iron unchanged; still gray.
Total from 4½ G.	52.5	83.46	....	.....	.....	58.31	65.19	123.5	.....	.....	
5.16 G. wrapped in pt. dull red heat	9	34.4	Trace	26.00	74.00	37.00	7.60	44.6	3.67	1.289	
5.16 G. red heat	15	18.2	.50	25.82	74.00	17.60	6.00	23.6	1.166	.404	
5.16 G. high red heat	12	17.4	.70	13.00	86.00	20.35	2.25	22.6	1.636	.244	
Total	36	70.0	....	.....	.....	74.95	15.95	90.80	.....	.....	
3.33 G. wrapped in pt. red heat	12	36.0	1.00	19.00	78.00	58.30	13.70	72.00	4.740	1.200	
3.33 G. full red heat	5	26.0	....	20.00	80.00	41.60	10.40	52.00	8.320	2.080	
3.33 G. full heat of furnace	42	35.2	....	33.30	66.00	46.90	23.40	70.30	1.102	.560	
Total	59	97.2	....	.....	.....	146.80	47.50	194.30	.....	.....	Outer tube melted; inner tube O. K.
Again	14.5	23.4	....	17.80	81.00	38.00	8.33	46.80	2.64	.58	Gas still evolved; Fe unchanged.

in the accompanying table, Parry[9] published the results of another series of experiments on the same subject. In order to ascertain whether or not he was correct in believing that iron carbide acted on porcelain, he analyzed some iron both before and after heating it for 48 hours in a porcelain tube. The results of this work are given below:

Contents of tube	Per cent. silicon	Per cent. carbon
Original sample	0.87	5.32
Sample after 24 hours in tube	1.07	3.90
Globule imbedded in tube	3.40	....
Cast steel	0.10	1.54
After 24 hours' fusion in Hessian crucible	0.26	0.74
After 2 hours' fusion in silicious crucible	0.80	0.70

Since the percentage of carbon is shown to have decreased, it was concluded that a large error was introduced in allowing the test samples to come in contact with porcelain, therefore, in all later work, crucibles of lime and of magnesia were used. Proceeding with his work, Parry obtained much larger quantities of gas than before. Gray iron heated for 165 hours evolved 205 times its own volume of hydrogen and 135 times its own volume of carbon monoxide. During the first 128 hours the ratio of hydrogen to carbon monoxide was one part of hydrogen to 0.9 part of carbon monoxide. During the last 36 hours the ratio was one part of hydrogen to 0.213 part of carbon monoxide. When heated in hydrogen, the iron (free of hydrogen and carbon monoxide) was found to absorb 20 volumes; when heated in carbon monoxide, the same iron did not absorb an appreciable amount of the gas, but after remaining in contact with the iron at red heat the carbon monoxide was found to contain 4.5 to 6 per cent. of carbon dioxide.

Bessemer steel of the following composition was treated:

Constituent	Per cent.
Silicon	0.08
Carbon	0.35
Manganese	0.72
Oxygen	0.28
Magnetic iron oxide	1.02

Ten grammes of this steel when heated to 1000° C. evolved gas as indicated:

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[9] *Jour. Iron and Steel Inst.*, 1881, 1, pp. 183–194.

Time of treatment	Cubic centimetres of gas	Per cent. carbon dioxide	Per cent. carbon monoxide	Per cent combustible
First 24 hours	45	2.58	67.74	29.68
Next 24 hours	41	0.66	41.80	57.54
Last 12 hours	5	1.44	8.39	90.07

The specific gravity of the sample being 7.75, one volume of steel evolved 70.5 volumes of gas. This same steel when heated at a low red heat, in an atmosphere of hydrogen, absorbed 6.6 cubic centimetres, or 5.116 volumes of gas; when the temperature was raised, 7.0 cubic centimetres was absorbed, making a total of 10.54 volumes absorbed.

At the time of its publication Parry's work was received with much skepticism. It was very generally believed that a great error was somewhere introduced on account of the large volumes of gas obtained. Parry himself admitted that there was a possibility that his tubes leaked at high temperatures, although he said that he had tested them by blank determinations and had found them to be air-tight. In order that any possibility of a leak at high temperatures might be eliminated, Parry designed a new type of apparatus for his work. This consisted of an evacuated glass tube in which the test specimens could be heated by passing an electric current directly through them. However, the apparatus was evidently not very satisfactory, as no results obtained by its use can be found. In the light of later discoveries by other investigators, it is now conceivable that Parry's tubes did not leak, but that the large volumes of gas actually were evolved from the iron and steel. However, the accuracy of Parry's work is still a matter of doubt.

About 1878, Fr. C. G. Müller[10] conceived the idea that the occluded gases could be liberated from iron and steel by broaching or boring the test specimens under water, in an apparatus constructed on the principle of the accompanying sketch.

The gas liberated by the bit (*B*) was collected in the hole bored in the metal and could be transferred to a burette for analysis. Samples of iron and steel were bored under water in this way and the gases collected and analyzed. The results were as follows:

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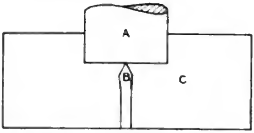
[10] *Ber. d. d. Chem. Gesells.*, 1879, 12, pp. 93–95; 1881, 14, pp. 6–14. Also, *Stahl u. Eisen*, 4, 1884, pp. 69–80.

Gas	Sample* (a)	(b)	(c)	(d)
Hydrogen	88.8	77.0	67.8	83.3
Nitrogen	10.5	22.9	30.8	14.2
Carbon monoxide	0.7	.....	2.2	2.5
Gas volume, sample volume	0.6	0.45	0.25	0.35

*(a) Bessemer steel before the addition of spiegel.
(b) Bessemer steel after the addition of spiegel (same charge as (a)).
(c) Martin steel
(d) Wrought iron.

Since such a large percentage of hydrogen was found, Müller thought that perhaps the warm filings were being acted on by the water in which the boring was being done. To prevent such an action, he treated some of the same metals under rape-seed oil and others under mercury. In all cases the results were identical with those obtained when the metals were bored under water. Müller therefore concluded that the gases must have come from the metal.



A. Test Specimen. *B*. Drill. *C*. H_2O tank.

There were great differences of opinion as to the value of Müller's method of extracting gases. J. E. Stead[11] showed that the volume of gases liberated by a blunt drill was much larger than that obtained by the use of a sharp one, the difference often amounting to one hundred-fold. E. W. Richards[12] decided that the discrepancy was brought about by larger volumes of hydrogen being formed by the decomposition of water when blunt drills were used. To confirm this theory, the cutting edge was removed from a drill and the blunt tool allowed to revolve in contact with a test sample for 24 hours. No hole was bored, yet large quantities of hydrogen were given off. From this Richards concluded that the water had been decomposed. However, Müller's experiments in which the materials were bored under rape-seed oil and mercury are not explained by Richards's theory.

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[11] *Jour. Iron and Steel Inst.*, 1882, 2, pp. 526, 572; 1883, 1, p. 114. Also, *Iron*, 1883, p. 115; 1884, p. 138.

[12] *Jour. Iron and Steel Inst.*, 1882, pp. 519–520.

As stated previously, Sir Henry Bessemer[13] had originally observed that molten steel appeared to evolve great quantities of carbon monoxide. When the steel was allowed to cool, violent bubbling occurred and frequently holes known as "blowholes" appeared in the cooled metal. Bessemer noticed that if pressure were placed on the mould in which the steel was cooling, the bubbling ceased, and steel free from "blowholes" was obtained. Bessemer's idea was later incorporated in the Whitworth patent. Müller analyzed a number of samples of gas taken from "blowholes" and obtained the following results:

Müller's Analysis of Gas from Blowholes

Material	Per cent. Ferro-manganese	Per cent. Ferro-silicon	Per cent. Gas evolved	Per cent. CO	Per cent. H	Per cent. N
Soft basic steel....	2.5	...	36.0	0.6	85.4	14.3
Basic steel........	...	...	20.0	...	64.5	35.4
Basic steel........	2.5	5.0	2.2	0.4	86.4	12.7
Basic steel........	...	5.0	6.0	.1.	54.7	45.3

Müller next conducted a comprehensive investigation on the gases evolved during the filling of moulds. A description of the metals and the analyses of the gases collected are given in tabular form as follows:

TABLE II.

Showing Gases Evolved During the Filling of Moulds—Müller.

(Description of material is on pages 176 and 177—see numbers.)

Material.	Composition of Material in Per Cent.					Composition of Gas in Per Cent.				
No.	Comb. C.	Free C	Si	P	Mn	CO	H_2	N_2	CO_2	O_2
1	.584	3.104	1.68	.....	1.93	36.1	55.8	3.6	3.7	.8
1a	.....	......	....	.....	....	37.3	58.3	.5	3.9	...
2	4.18	......	.253	.....	7.37	48.1	48.9	2.0	1.2	.4
2a	.....	......	....	.....	....	48.7	49.5	.5	1.5	...
3	3.09	......	.203	3.025	.73	37.1	43.7	14.2	3.3	1.2
3a	.....	......	....	.....	....	39.6	46.8	10.0	3.8	...

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[13] *Ibid.*, 1881, 1, pp. 197–199.

TABLE II.—*Continued.*

Material.	Composition of Material in Per Cent.					Composition of Gas in Per Cent.				
No.	Comb. C	Free C	Si	P	Mn	CO	H_2	N_2	CO_2	O_2
4	.23	......	.15	.06	.5	35.5	45.3	11.3	7.0	1.0
4	.28	......	.26	.08	.06					
4*a*	.....	......	......	.....	....	37.3	47.3	7.9	7.5	...
5						24.1	35.1	29.3	5.9	5.6
5*a*						34.0	49.5	8.6	7.9	...
6	.48	......	.15	.06	.8	41.7	19.1	37.9	.4	.7
6*a*	.53	......	.25	.08	.9	43.2	19.7	36.7	.4	...
7						....	....	....	...	...
7*a*						45.9	41.4	9.9	2.8	...
8	Presumably same as No. 4					38.7	51.3	7.2	2.8	...
8*a*	.....	......	......	.....	....	43.4	46.9	6.6	3.1	...
9	Presumably same as Nos. 5 to 7					48.2	44.5	2.5	4.8	...
9*a*	.....	......	......	.....	....	42.5	36.5	17.1	3.7	...
10	?	?	?	?	?	33.0	47.4	10.0	7.6	2.0
10*a*	.....	......	......	.....	....	38.4	51.0	2.2	8.4	...
11	?	?	?	?	?	30.2	37.5	23.8	7.4	.8
11*a*	.....	......	......	.....	....	31.5	39.2	21.6	7.7	...
12	?	?	?	?	?	68.6	19.8	9.0	2.0	.8
12*a*	.....	......	......	.....	....	70.7	20.7	6.5	2.1	...
13	?	?	?	?	?	15.6	45.4	33.7	1.8	3.2
13*a*	.....	......	......	.....	....	18.6	54.2	24.9	2.3	...
14	?	?	?	?	?	17.5	61.1	29.1	2.2	.8
14*a*	.....	......	......	.....	....	18.1	52.9	26.8	2.2	...
15	?	?	?	?	?	36.5	26.7	30.5	1.3	4.7
15*a*	.....	......	......	.....	....	48.0	35.1	15.4	1.5	...
16	?	?	?	?	?	39.0	36.9	17.8	2.9	3.0
16*a*	.....	......	......	.....	....	46.0	43.6	6.9	3.4	...
17–	.05	......	Trace	.05	.45	....	....	....	....	...
22	.10	......	Trace	.10	.55	....	....	....	...	...
17–22*a*	....	......	......	.....	....	65.0	5.0	30.0	...	...
23	.25	....	Trace	.05 .10	.45 .55	67.2	15.8	12.0	4.7	.3
23*a*	.....	......	......	.....	....	68.0	16.2	11.0	4.8	...
24	?	?	?	?	?	56.5	33.0	8.6	1.9	...
25	?	?	?	?	?	62.0	34.2	1.0	2.8	...
26	.....	......	......	.....	....	77.9	5.7	14.7	1.7	...
26*a*	....	......	......	.....	....	62.6	12.6	23.2	1.6	...
27	.....	......	......	.....	....	81.7	8.2	9.5	.6	...
27*a*	.....	......	......	.....	....	54.1	38.6	3.5	3.8	...
28	.....	......	......	.....	....	8.0	71.7	18.0	2.0	...
28*a*	.....	......	......	.....	....	8.8	71.9	18.1	2.0	...
29	.....	......	......	.....	....	19.3	30.7	41.7	2.1	5.8
29*a*	.....	......	......	.....	....	27.3	43.5	26.2	3.0	...
29*b*	.....	......	......	.....	....	29.2	32.0	32.0	3.4	3.3
29*c*	.....	......	......	.....	....	35.0	38.4	22.5	4.1	...
30	.....	......	......	.....	....	58.3	17.0	19.9	1.9	1.8
30*a*	.....	......	......	.....	....	64.6	18.9	14.4	2.1	...
30*b*	.....	......	......	.....	....	36.2	34.1	22.7	3.0	3.7
30*c*	.....	......	......	.....	....	44.1	41.6	10.6	3.7	...
31*a*	.002	......	.002	.078	.083	....	....	....	...	...
31*b*	.115	......	.162	.097	.944	....	....	....	...	...
31*c*	.14	......	.53	.....	1.25	....	....	....	...	...
31*d*	.....	......	......	.....	....	34.7	58.0	4.1	3.2	...
31*e*	.....	......	......	.....	....	30.8	65.8	1.9	1.5	...

DESCRIPTION OF THE MATERIAL USED IN MÜLLER'S EXPERIMENTS.

A.—Pig Iron.

No. 1. Gray Bessemer pig iron: Copious evolution of gas; block dense, fine grained, and gray, with white crust 1 mm. thick.

No. 1*a*. After calculating the oxygen to air, deducting the corresponding nitrogen, and recalculating to 100.

No. 2. Spiegeleisen: Abundant gas; block dense, flaky, and crystalline.

No. 2*a*. After correction as above.

No. 3. Thomas iron: Less gas than with 1 and 2. Block free from bubbles; radial.

No. 3*a*. Corrected as above.

B.—Bessemer Products.

No. 4. Rail steel: Dense, blown from hot, fused charge with moderate Si and Mn content.

No. 4*a*. Corrected.

No. 5. Spring steel: Dense (cast from above).

No. 5a. Corrected.

No. 6. The same (poured from below).

No. 6*a*. Corrected.

No. 7. The same (without further details).

No. 7*a*. Corrected.

No. 8. Rail steel: Dense, first mould (corrected).

No. 8*a*. After 17 minutes last mould (corrected).

No. 9. Spring steel: Dense, first mould (corrected).

No. 9*a*. After 21 minutes, last mould (corrected).

No. 10. Rail steel: Swelling.

No. 10*a*. Corrected.

No. 11. Rail steel: Swelling more strongly.

No. 11*a*. Corrected.

No. 12. Rail steel: Swelling still more strongly, very restless.

No. 12*a*. Corrected.

No. 13. Bessemer steel: Completely decarbonized and hot-short, before addition of spiegeleisen. Swelling and copious liberation of gas, zone of worm casts, and single bubbles in centre; first gas sample.

No. 13*a*. Corrected.

No. 14. Bessemer steel: Completely decarbonized and hot-short, before addition of spiegeleisen. Swelling and copious liberation of gas, zone of worm casts, and single bubbles in centre; second gas sample.

No. 14*a*. Corrected.

No. 15. Martin steel: Completely decarbonized, as comparison; first gas sample.

No. 15*a*. Corrected.

No. 16. Martin steel: Completely decarbonized, as comparison; second gas sample.

No. 16*a*. Corrected.

C.—Thomas Products.

No. 17 to 22. Thomas metal: Soft, prepared with 95 per cent. ferromanganese; no strong spiegel or ferromanganese reaction; brisk liberation of gas in pots and moulds; poured from below.

No. 17 to *22a*. Mean of corrected analyses.

No. 23 Rail steel: Produced by the addition of 8 per cent. of fused spiegeleisen; strong spiegel reaction.

No. *23a*. Corrected.

No. 24. Rail steel: Produced by the addition of 10 per cent. of spiegeleisen; strong spiegel flame; restless product, rapid swelling; gas from above from fourth block; analysis corrected.

No. 25. Rail steel: Produced by adding 10 per cent. of spiegeleisen; strong spiegel flame; restless product, rapid swelling; gas from above from last block (after nine minutes); analysis corrected.

No. 26. Ingot iron: Gas from below, sampling to be removed directly mould was full.

No. *26a*. Ingot iron: Gas from above by means of sand cover, not filled until mould had set; from same mould.

No. 27. Rail steel similarly treated; first gas sample.

No. *27a*. Same as No. 27; second gas sample.

No. 28. Ingot iron: Little gas, completely decarbonized, and before the introduction of reducing agents.

No. *28a*. Corrected.

No. 29. Ingot iron: Gassy, completely decarbonized; first gas sample.

No. *29a*. Corrected.

No. *29b*. Second gas sample.

No. *29c*. Corrected.

No. 30. Ingot iron: Prepared with 5 per cent. of 14 per cent. silicide and 2.5 per cent. of 70 per cent. ferromanganese; steel swelling gently, moderately porous (see first table, sample last but one); gas sample from small mould at commencement of pouring.

No. *30a*. Corrected.

No. *30b*. Gas sample from larger mould at end of pouring.

No. *30c*. Corrected.

No. *31a*. Ingot iron: With 5 per cent. of same silicide and 2 per cent. of ferromanganese added red-hot in the pot; no reaction, steel quiet; swelling later with formation of porous zone—before addition.

No. *31b*. After addition.

No. *31c*. (Calculated.)

No. *31d*. Gas from one mould.

No. 31e. Gas from another mould.

From the data collected during his investigations Müller arrived at the following conclusions: *

" 1. Molten iron and steel contain a mixture of gas consisting of carbon monoxide, hydrogen, nitrogen and carbon dioxide, with small portions of free oxygen. The mixture is of variable composition, and the gases are present partly in solution and partly in combination (alloyed); hydrogen and nitrogen are alloyed with the iron, and carbon monoxide is present in solution.

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* Von Jüptner: "Siderology," p. 284.

"2. As cooling proceeds, there is liberated a mixture of gases, consisting chiefly of carbon monoxide, hydrogen, and nitrogen, the percentage composition fluctuating between certain limits, according to the nature and treatment of the iron.

"3. The solidified metal retains a quantity of imprisoned gas, which may be liberated by broaching. This gas consists mainly of hydrogen and nitrogen, with a small percentage of carbon monoxide.

"4. By heating the metal to redness in a vacuum, small quantities (to be regarded as combined remainders) of the elementary gases can be driven out and determined.

"5. The use of silicon-manganese results in the production of a steel which does not evolve gas during solidification. This phenomenon is probably due to the fact that the silicon-manganese steel becomes supersaturated with gas."

Upon examining the results obtained by Müller in his experiments on broaching under water, it is found that the volume of gas he obtained per unit volume of metal is much smaller than the volumes obtained by Graham and Parry. It seems very probable, therefore, that broaching does not liberate all the gas, and therefore Müller's work does not contribute marked advance over the results obtained by earlier investigators.

A. Pourcel[14] conducted a number of experiments dealing with the effects produced on steel by the addition of silicon and manganese. He found that castings free from blowholes could be produced by the addition of alloys of silicon, manganese, and iron, with a minimum of carbon. If ferromanganese was added to a bath of molten metal, a violent reaction occurred, accompanied by the evolution of carbon monoxide. The resulting castings contained large numbers of blowholes. If silicide of manganese was added, no bubbling of gas was evident, and castings free from blowholes were produced, although flames of hydrogen were visible at the point of solidification. If silicon was added as silicide of iron, hydrogen could not be thus detected, and no blowholes were formed. From the above results it was concluded that silicon steel contained almost no gas unless manganese was present. The gas was found to increase with the percentage of manganese until, with 2 per cent. of manganese, the largest amount of gas with a maximum content of hydrogen was found to be present. Aluminum produced the same effect as silicon.

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[14] *Jour. Iron and Steel Inst.*, 1882, pp. 509–518.

Pourcel disagreed with Müller as to the manner in which the carbon monoxide was occluded. Pourcel assumed that the carbon monoxide was formed by the action of oxygen on the carbon in the steel. The affinity of silicon and aluminum for oxygen being greater than the affinity of carbon for oxygen, when the two first-named elements were present, they acted as reducing agents and no gas was formed. Pourcel's theory became known as the "reaction theory," whereas Müller's theory that the carbon monoxide was in solution in the steel was called the "solution theory."

Considerable information as to the nature of the gases occluded in weld and ingot iron is given in the results of a series of investigations by Zyromski,[15] in which he extracted the gas from the metal under examination by means of an apparatus resembling that used by Graham. Identical portions of pig iron were converted into puddled and ingot iron, respectively, and the gases extracted from the finished products analyzed. The following table shows the analyses of the gases evolved from four test bars of ingot and four of puddled iron:

Determination	Material	Weight of bar in grammes	Volume of gas per cubic centimetre of sample	Percentage composition		
				H	CO	N
1	Ingot iron........	24.242	16.00	58.4	5.6	36.0
2	Ingot iron........	23.650	18.55	60.9	5.9	33.2
3	Ingot iron........	24.450	16.95	52.5	13.5	33.9
4	Ingot iron........	24.432	16.80	56.8	6.8	36.4
5	Puddled iron.....	24.353	16.15	27.8	40.3	31.8
6	Puddled iron.....	23.995	14.10	15.6	45.3	39.0
7	Puddled iron	24.851	16.55	30.8	45.4	23.8
8	Puddled iron.....	23.453	15.25	22.3	45.5	32.1

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[15] *Compt. rend. de la Société de l'Industrie Minerale*, 1884, pp. 101–108.

The composition of the metal tested was stated to be as follows:

Element	Ingot iron	Puddled iron
Carbon	0.050 per cent.	0.030 per cent.
Silicon	Trace	
Sulphur	Trace	
Phosphorus	0.024 per cent.	0.078 per cent.
Manganese	0.288 per cent.	0.200 per cent.

The results of the gas analyses show that, while the volumes of the gases contained in the two products were approximately the same, the puddled iron contained about five times as much carbon monoxide as the ingot iron, but considerably less hydrogen.

In his "Metallurgy of Steel" (pp. 105–145), published in 1892, Henry Howe gave an excellent *résumé* of the results obtained to that date concerning the subject of occluded gases. Howe considered that occluded gases might be divided into four separate and distinct classes: (1) Those chemically combined; (2) those in solution; (3) those in adhesion; (4) those mechanically retained in the pores of the metal. Of these four states, the first three are non-gaseous and the fourth alone is gaseous. Howe discussed the relationship between iron and nitrogen, iron and hydrogen, and iron and carbon monoxide, laying particular emphasis on the effects which these gases produce on the physical properties of the metal. His discussion may be summarized as follows:

Iron and Nitrogen.—Iron changes in appearance on being heated in a stream of ammonia, the metal becoming brittle and acquiring a bright fracture. The change is due to the absorption of nitrogen, hydrogen being set free.

Nitrogen imparts a relatively low ductility to steel.

Nascent iron absorbs nitrogen from the atmosphere, the nascent iron being formed by the reduction of iron oxide by carbon.

Ammonia, as such, can be occluded by iron, a distinct odor of ammonia having been detected upon fracturing castings.

Iron and Hydrogen.—Molecular hydrogen appears to have little effect on iron. In one case, after occluding 46 volumes of hydrogen, iron was found to have acquired a slightly white color; and, in another case, after being heated for some hours in hydrogen, the iron was found to have become slightly brittle, crystalline, and of a steel-like appearance.

Nascent hydrogen causes iron to become brittle, affects the elongation of iron anomalously, causes the flexure of iron to fall, and decreases the cross-sectional strength of steel springs from 14.6 to 47.6 per cent.

Contact with zinc intensifies the above effects, and heating or resting restores the iron to its original condition.

Iron and Carbon Monoxide.—There is but little evidence that carbon monoxide influences the properties of iron. Possibly it acts slightly like phosphorus and makes iron cold short. It is suggested that, since Whitworth's liquid compression increases the quantity of gas dissolved, and since the steel manufactured by Whitworth's method is of very good quality, carbon monoxide cannot exert a harmful influence on the steel.

Howe's conclusions as to the manner in which the above gases are inclosed in iron and steel are given in his own words, as follows:

" To sum this discussion up, very numerous analyses of the gases which iron evolves, before, during, and after solidification, on boring and on heating *in vacuo,* prove that these gases usually consist chiefly of hydrogen and nitrogen which, according to the definitions made in order to render discussion of the points at issue possible, must escape from solution.

" But, wholly independently of this conclusive evidence, the behavior of gases toward iron, their absorption and release from both solid and molten metal on rise and fall of pressure, their expulsion on solidification and agitation, their protracted escape, and the shape and position of the cavities which they form, is closely analogous to their behavior towards other solvents. The closeness of this analogy; our inability to reconcile the copious escape of gas from iron low in silicon with the complete arrest of the escape of gas by slight additions of this element on the 'reaction theory,' and the complete accord of these phenomena with the ' solution theory '; the fact that gases are copiously evolved from both oxygenless and nearly carbonless iron and from other classes in which no gas-forming reaction is to be looked for; and that their escape cannot be accounted for qualitatively or quantitatively by purely mechanical retention of insoluble gas, all point with varying degrees of certainty and, taken collectively, lead irresistibly to the conclusion that gases dissolve in iron, and that at least a very large part of these gases, whose escape forms blowholes, are dissolved in the metal before that escape.

"If successful, the attempt to show that the hydrogen and nitrogen alone found in boring cold iron proceed from the water in which it is bored, and not from the iron, would not seriously bear against the remaining evidence and reasoning. But the ratio of nitrogen to hydrogen in these gases and their freedom from oxygen; the fact that the gases obtained in the two instances in which iron has been bored under oil and mercury resembled in composition those obtained on boring under water; the fact that compact yields less gas than porous iron, and the arrangement of the boring apparatus, collectively argue cogently against the aqueous source of the gases. That the absence of carbonic oxide from these gases is not due to its conversion into carbonic acid and subsequent absorption by the boring water is indicated by the facts that this conversion could not be complete, that neither carbonic oxide nor acid is found on boring under oil and mercury, and that in case of blisters both these gases are found even on boring under water.

"Further, the changes in the composition of the gases evolved from iron, so far as we have studied them, are quite compatible with the view that they are evolved from solution.

"Turning now to carbonic oxide, which accompanies hydrogen and nitrogen in all except the boring gases, there is reason to believe that, in spite of its absence from the blowholes when the metal is cold, it coöperates in forming them while the metal is hot, and is later reabsorbed or decomposed. (1) The general similarity of its behavior to that of hydrogen and nitrogen; (2) its expulsion and absorption under falling and rising pressure; (3) its escape, occurring when no reaction is to be expected, and arrested by silicon when this element appears to act on the solubility and not by being preferentially oxidized; these three collectively very strongly indicate that carbon oxide dissolves, and it may reasonably be held that they do not prove it. Were carbonic oxide known to dissolve, then in coöperating with hydrogen and nitrogen in the formation of blowholes it would be most natural to suppose that, in the majority of cases, it escaped from solution like its companions.

In a word, it is practically certain that in the many and important classes of cases which have been studied the blowholeforming gases are chiefly hydrogen and nitrogen escaping from solution; it is extremely probable that carbonic oxide coöperates, and that it, too, comes in large part from solution. Under other and yet unstudied conditions air mechanically drawn down in teeming may, however, prove to be an important cause of blowholes."

During 1903–1906 Hjalmar Braune[16] discovered that iron manufactured in certain Swedish blast furnaces was brittle and non-elastic. He ascribed these properties to the high nitrogen content of the iron, it having been known since 1860[17] that a high nitrogen content tends to make iron brittle. During his researches Braune decided that the nitrogen was present in the iron in two forms—nitrogen held mechanically and nitrogen held chemically—and that the brittleness of certain grades of iron was due to the chemically combined nitrogen. He accepted the experiments of Müller and of Stead as typifying the liberation of mechanically held nitrogen, and then conducted some investigations with the object of discovering the form in which the chemically combined nitrogen was present. In order that cyanides might be tested for, some of the Swedish iron was dissolved in hydrochloric acid, and the gas evolved was tested for hydrocyanic acid. None was present, and Braune therefore concluded that the nitrogen was not present as a cyanide. Another sample of the same iron was dissolved in hydrochloric acid and tests for ammonia made. Large quantities of ammonia were dissolved. A sample of iron nitride was treated with hydrochloric acid and the same result was obtained, and it was therefore concluded that the nitrogen was present as iron nitride, having the probable formula Fe_5N_2.

Braune likewise discovered that the presence of nitrogen in iron could be detected by means of photomicrographs. Iron free from nitrogen appeared to be composed of large cells having a uniform surface, and to be marked by a number of parallel striations of corrosion. Some cells seemed to have disappeared altogether, and a crystalline structure developed in their place. With a nitrogen content of 0.07 per cent. to 0.08 per cent. the cells were about one-tenth of their original size; with a nitrogen content of 0.02 per cent. the cells had entirely disappeared, the resulting crystalline structure very closely resembling that of pearlite.

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[16] *Stahl u. Eisen*, **26**, 1906, pp. 1357–1363, and *Revue de Metall.*, 1905, pp. 497–502; *Ibid.*, 1907, p. 834.

[17] Fremy, *Compt. rend.*, **52**, 1861, p. 323.

Nitrogen was found to affect the temper and also to augment the coercitive force and the hysteresis effect of steel.

As has been stated previously, the presence of blowholes had been recognized for a number of years, and many investigators had sought to discover some means by which these imperfections could be avoided. In 1907 W. Kusl[18] endeavored to show that carbon monoxide was the chief cause of blowholes. Kusl considered that the greater part of the hydrogen and nitrogen originally present was evolved before the metal solidified, and, in proof of his theory, analyzed the gases obtained from a number of blowholes. It was found that carbon monoxide was present in large percentages, with smaller amounts of hydrogen and nitrogen, as the following table indicates:

Gas	Per cent.
Carbon monoxide	52.00
Hydrogen	27.46
Carbon dioxide	7.40
Nitrogen	13.20
Total	100.06

Kusl concluded that sound castings could be best obtained by dealing as far as possible with the carbon monoxide, the source of the reaction blowholes; by using warm and well-dried moulds; and by rapid after-pouring. He concluded further, however, that there was at that time no practical method of entirely avoiding the formation of blowholes.

E. von Maltitz[19] conducted a number of investigations on the problem of discovering whether or not molten steel absorbed gas. He concluded that heating to very high temperatures seemed to diminish any tendency to this action, should any exist, since steel poured extremely hot (and without over-oxidation) yielded perfectly solid ingots and castings. Analyses of the gases obtained from a number of blowholes were made, and it was found that the gases varied widely in composition and always contained far higher proportions of hydrogen than of nitrogen. This may be seen from the following table, giving the results of Maltitz's analyses:

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[18] *Osterreichische Zeitschrift für Berg. und Hüttenwesen*, **54**, pp. 593–598; 610–613.

[19] *Bi-monthly Bull. Am. Inst. Min. Eng.*, 1907, pp. 691–726.

Gas	Per cent.
Hydrogen	54.7 to 92.4
Nitrogen	5.9 to 45.3
Carbon monoxide	0.0 to 2.2

Von Maltitz was unable to determine the form in which the hydrogen was present, but stated that it seemed to be alloyed with the metal.

Analyses of gases from cooling ingots showed a composition differing considerably from that of the gases obtained from blowholes:

Gas	Per cent.
Hydrogen	16.2 to 54.2
Nitrogen	2.2 to 36.7
Carbon monoxide	18.1 to 68.0
Carbon dioxide	Small amounts

From the above results von Maltitz arrived at the following conclusions:

1. Although practically only hydrogen and nitrogen are found in blowholes, these two gases are not entirely responsible for blowholes.

2. An important factor is carbon monoxide, which is present in large quantities in solidifying steel.

3. The source of the carbon monoxide is the ferrous oxide dissolved by the steel during its manufacture.

4. The solvent power of steel for ferrous oxide increases with the temperature.

5. Steel also dissolves ferrous oxide in proportion to the purity of the steel.

6. The affinity of iron for oxygen at high temperatures increases more rapidly than the affinity of carbon for oxygen.

Von Maltitz next considered the physical conditions attending the formation of blowholes, and suggested methods for their complete elimination. These methods included the prevention of over-oxidation, the reduction of the oxidized material, and a choice between "heat finishing" in the furnace. The influence of the presence of carbon manganese, silicon, and aluminum in preventing blowholes was also considered. Incidentally it was observed that pig iron did not form blowholes on freezing. It was concluded that the absence of blowholes was due to the fact that pig iron possesses a very low solvent power for ferrous oxide and also to the fact that there was no pasty state intermediate between the molten and solid states. Reference was made to the effect of stirring the steel in the ladle, the variation in the methods of pouring, and the influence exerted by increased and decreased pressure. The following precautions are suggested in order to prevent the formation of blowholes:

"1. During the last period of the process, in the converter or open-hearth furnace, the melt should be held at a medium temperature.

"2. Excessive additions of ore and 'over-blowing' should be avoided.

"3. The finishing slag should not be too rich in oxygen and should have a proper degree of fluidity.

"4. Ferrous oxide should be decomposed by stirring the heat before tapping. There should be added sufficient oxidizing materials for the separating of manganese protoxide, and the silicate of manganese or aluminum formed in the slag."

Two Frenchmen, G. Belloc and O. Boudouard, working independently, have made many contributions to the knowledge of occluded gases.

In his earlier work Belloc[20] sought to establish some relationship between the temperature (t) of the iron, the rate of evolution (dv/dt) of the gas, and the composition of the gas. He used an externally glazed porcelain tube about 60 cm. long and heated it electrically. The method of heating is not described in detail. Temperatures were measured with a Le Chatelier pyrometer. The steel used was of the following composition:

Element	Percentage
Carbon	0.12
Silicon	0.03
Sulphur	0.02
Phosphorus	0.018
Manganese	0.36

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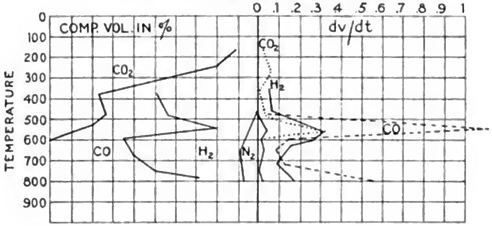
[20] *Compt. rend.*, **145**, 1907, pp. 1280–1283; *Revue de Metall.*, **5**, 1908, pp. 469–488.

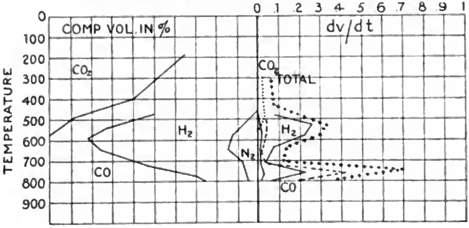
Some of the results which Belloc obtained by heating the steel to 1000° to 1100° C. for several days at a time are shown in Table III on page 28.

From Belloc's figures it is seen that the evolution of gas began at 150° to 400° C. (*dv/dt*), had a minimum value at 200° C. and a maximum at 400° C. Between 500° and 600° C. there was a high maximum, falling off to a minimum at 600° C.

CURVES FOR DETERMINATION °1 - BELLOC.



CURVES FOR DETERMINATION °2 - BELLOC.



Upon heating the metal above 600° C., the evolution of gas increased. At 1200° C. the volume of gas obtained was eleven or twelve times the volume of the steel. The gas evolved up to 400° C. was mostly carbon monoxide, which was not present in the sample taken at 550° C. Above 400° C. hydrogen was evolved, and the gas given off above that temperature consisted almost completely of hydrogen, although above 550° C. a quantity of nitrogen, not exceeding 10 per cent., appeared.

TABLE III.

Determination Number 1.—Belloc.

Temperature	Vol. (v), extracted in c.c.					dv/dt					Composition per cent. in volumes			
t	Total	CO_2	CO	H_2	N_2	Total	CO_2	CO	H_2	N_2	CO_2	CO	H_2	N_2
150	.26	.24									90			
190	.10	.09				.03	.02				90			
250	.40	.35				.07	.06				80			
280	.35	.25				.12	.08				70			
390	.80	.20	.20	.40		.07	.02	.02	.04		25	25	50	
480	1.15	.32	.32	.51		.13	.04	.04	.06		28	28	44	
540 *a*	2.60	.50	1.75	.35							34	52	14	
b	1.50	.36	.80	.34							34	54	22	
c	1.95	.70	1.05	.15	.05						36	54	8	2
d	.90	.10	.53	.24	.03	1.84	.37	1.11	.33	.03	11	60	27	2
e	1.70	.10	1.10	.47	.03						6	65	28	1
f	1.85	.35	1.10	.36	.04						19	60	20	1
g	.60	.10	.37	.08	.05						16	62	13	9
600 *a*	1.41	.02	.33	.01	.05	.42		.14	.26	.02	2	23	72	3
b	1.10	.01	.50	.53	.06						1	45	48	6
660 *a*	1.10		.49	.52	.09	.27		.10	.14	.03		45	47	8
b	.51		.14	.31	.06							27	61	12
730 *a*	1.00		.52	.44	.04	.23		.12	.10	.01		52	44	4
b	.63		.33	.28	.02							..	..	..
800 *a*	1.55		1.10	.39	.06							71	25	4
b	1.90		1.48	.36	.06	.79		.57	.19	.03		78	20	2
c	1.35		.97	.32	.06									
d	.72		.41	.25	.06							57	35	8
	25.43	=4 times vol. of steel.												

50 G. of steel used.

TABLE III.

Determination Number 2.—Belloc.

Temperature	Volume (v), extracted in c.c.					dv/dt					Composition, per cent. in volumes			
t	Total	CO_2	CO	H_2	N_2	Total	CO_2	CO	H_2	N_2	CO_2	CO	H_2	N_2
200	.15	.10									65			
310	.30	.15				.03	.01				50			
390	.20	.08				.03	.01				40			
480	1.05	.16	.27	.62	N_2	.13	.02	.03	.08		15	26	59	
520	1.42	.10	.17	1.08	.07	.35	.03	.04	.27	.02	7	12	76	5
580 *a*	1.25		.13	.96	.16	.30		.03	.24	.04		10	77	13
b	.58		.03	.48	.07							5	83	12
630	.60		.08	.43	.09	.12		.02	.09	.02		13	72	15
710	.80		.28	.45	.07	.10		.04	.06	.01		35	56	9
760 *a*	1.52		.84	.60	.08	.71		.42	.26	.03		55	40	5
b	1.20		.75	.41	.04							63	34	3
c	.83		.50	.30	.03							60	36	4
800	1.19		.79	.34	.06	.30		.20	.09	.02		66	29	5
	11.09	= 1.15 ti	mes vol.	of steel.										

75 G. of steel used.

TABLE IV.

Gases Occluded in a Special Nickel Steel—Belloc's Work.

DETERMINATION NO. 1—50 GRAMMES OF FILINGS.

Temperature, t	Volume (v) Cubic centimetre	dv/dt	Composition per cent. of the gas in volume			
			CO_2	CO	H_2	N_2
480	5.60	0.3	34	51	15	0
540	2.05	.3	1	58	35	6
690	3.20	.2	0	69	27	4
820	4.20	.32	0	76	16.6	7.4
960 a.	5.30	.4	0	75	11	14

Total volume .....21.15—3.5 times the volume of the metal.

DETERMINATION NO. 2—50 GRAMMES OF WIRE.

Temperature, t	Volume (v) c.c.	dv/dt	Composition per cent. of the gas in volume			
			CO_2	CO	H_2	N_2
350	0.95	....	37	40	23	0
440	1.36	0.15	14	26	60–	0
540	3.00	.30	12	17	63	8
610	3.70	.53	8	49	39	4
640 a.	8.30	3.50	0	57	37	6
640 b.	2.14	....	0	50	44	6
710	7.70	1.10	0	57.8	40	3.2
740	2.70	.90	0	49	47	4
760	4.00	2.00	0	49	47	4
820	2.35		0	56	40.8	3.2
830 a.	12.50	2.40	0	57	40.8	2.2
830 b.	2.35		0	57	40.8	2.2
950	11.20	.93	0	67	28.5	4.5

Total volume .....61.97—10 times the volume of the metal

Belloc[21] also experimented with a special nickel steel containing 45 per cent. nickel and 0.15 per cent. carbon. Table IV shows the gases obtained from this material. It will be observed that the gases found consisted of carbon dioxide, carbon monoxide, nitrogen, and hydrogen. It was found that carbon dioxide was completely evolved at 520° C., but that, at that temperature, the nitrogen had just begun to appear. Part of the material used was in the form of wire and part in the form of filings. A comparison between the results obtained with these two forms is very interesting. From the filings a total gas volume equal to three and one-half times the volume of the alloy used was obtained. A curve between (t) and (dv/dt) was obtained which was nearly parallel to the temperature axis. The yield of carbon monoxide equalled 75 per cent. The rate of evolution of hydrogen reached its maximum at 540° C., and then gradually decreased. The volume of gas obtained from the wire was ten times the volume of the alloy used. The curve *(dv/dt)* showed two very sharply prominent maxima at 540° C. and 930° C. At 540° C. a minimum of carbon monoxide and a maximum of hydrogen were observed. Above 540° C. the amount of carbon monoxide increased, but very irregularly. The difference between the absolute gas volumes obtained at the same temperatures from filings and from wires can be attributed to:

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[21] *Revue de Metall.*, 5, 1908, pp. 571–574.

1. A very unequal distribution of gas in the block. Such a condition has been found to be the case in carbon steels.

2. A large loss in mechanically enclosed gas by the mechanical action of the drills.

3. An absorption of gas during the necessary operations of wire-drawing.

Boudouard[22] carried out a number of determinations by heating samples in an apparatus consisting of: a glazed porcelain tube, about 40 cm. long and 1.9 cm. in external diameter, enclosed in a similar tube, about 46 cm. long and 3.6 cm. in external diameter. By means of this arrangement it was hoped to decrease the possibility of leakage at high temperatures.

The grades of iron used in the determinations were: (1) commercial iron in the form of a bar one square cm. in cross-section (0.099 per cent. carbon); thin plates, 1 mm. thick (0.13 per cent. carbon); 2 mm. thick (0.188 per cent. carbon); 1 mm. thick (0.074 per cent. carbon); and ½ mm. thick strong wire (0.047 per cent. carbon). In the first experiments the materials were slowly heated to the desired temperature, 900° to 1100° C., for a period of one-half hour. The temperature was then held constant at its maximum for one hour, and the tube kept evacuated during the cooling process. The gas evolved was collected and analyzed. Two determinations were made at 445° C. For the first determination, the material was in the form of wire; for the second, filings were used. The first determination yielded a negative result, but in the second case 6.45 c.c. of gas especially rich in hydrogen and carbon monoxide was evolved. Thus it would appear that the physical condition of the metal influenced the development of the gas. It was determined, however, that, in all cases, using wire, bar, or filings, evolution of the gases commenced at red heat.

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[22] *Compt. rend.*, **145**, 1907, pp. 1283–1284; *Revue de Metall.*, 1908, **5**, pp. 69–74; *Bull. Soc. Chim.*, 1908, 3, pp. 247–254; 1908, 5, pp. 69–74.

The composition of the gas evolved at the higher temperatures was studied in two series of analyses, and between each series of two consecutive heatings the material was permitted to lie exposed to the air. As may be seen from Table V, it was exceedingly difficult to remove all of the gas. Even after the third heating gas was evolved, the volume of which depended very largely on the size of the particles of the metal used. Since it was observed that the volume of gas evolved diminished with each heating, it was concluded that a single heating at a temperature sufficiently above 1100° C. to melt the material should evolve all the occluded gas. With the apparatus used, however, it was impossible to obtain such a temperature, as the porcelain tubes leaked above 1100° C. As noted in Table V, the gas evolved consisted mostly of hydrogen and carbon monoxide. At high temperatures the amount of carbon dioxide diminished and that of hydrogen and of carbon monoxide increased. Boudouard concluded that the carbon in the gases formed was due to the combustion of the carbon in the metal (Table V), and also that the volume of gas evolved was proportional to the masses of sulphur and phosphorus in the iron and steel being investigated. Another interesting fact brought to light at this time was that the iron used commenced to volatilize at 900° C., and that this volatilization became very noticeable at 1100° C.

In 1909, E. Goutal[23] published a description of a newly discovered method for the determination of occluded gases. The metal on which he conducted his experiments was dissolved in a slightly acid solution of the double chloride of copper and potassium at a temperature of 40° C. A gas containing a small proportion of carbon monoxide equal in volume to from one-third to four-fifths the volume of the steel used was evolved. It should be noted, however, that Goutal's investigations could not be very exhaustive, since the results for hydrogen obtained were necessarily nullified by the fact that the solution used was acidic.

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[23] *Seventh Inter. Cong. Appl. Chem.*, 1909; also, *Metallurgie*, 7, 1910, p. 340.

TABLE V.

Number 1; Series Number 1.—Boudouard.

Nature of metal	Mass G.	Vol. c.c.	Surface sq. cm.	1. Heating to 900° C.		2. Heating to 900° C.			1. Heating to 1100° C.			2. Heating to 1100° C.		
				Vol. of gas, c.c.	Vol. of gas / vol.of metal	After days	Vol. of gas, c.c.	Vol. of gas / Vol.of metal	After days	Vol. of gas, c.c.	Vol. of gas / Vol.of metal	After days	Vol. of gas, c.c.	Vol. of gas / vol.of metal
Wire of .5 mm.	4.25	.545	33	5.8	10.6	60	1.8	3.3	30	6.2	2.2	19	6.7	2.4
Wire of 1 mm.	5.0	.641	33	4.0	6.2		1.85	2.8						
Wire of 2 mm.	12.0	1.538	33	6.15	4.0		4.15	2.7						
Wire of .5 mm.	39.5	5.1	308	45.0	8.8				32	9	1.8	14	4.06	.8
Wire of 1 mm.	31.0	4.0	165	26.1	6.5				32	4.05	1.0	16	2.25	.56
Wire of 2 mm.	61.0	7.692	163	51.0	6.6				36	15.5	2.0	19	8.6	1.1
Bar of 1 cm.	38.7	5.0	22	7.1	1.4				33	3.5	.7	22	2.85	.57
Plate of 1 mm.	56.5	7.25	120	27.0	3.7				33	16.0	2.2	22	10.65	1.5

Number 2; Series Number 2.—Boudouard.

Nature of metal	Mass G.	Vol. c.c.	Surface sq. cm.	1. Heating to 1100° C.		2. Heating to 1100° C.			3. Heating to 1100° C.		
				Vol. of gas, c.c.	Vol. of gas / Vol.of metal	After days	Vol. of gas, c.c.	Vol. of gas / Vol.of metal	After days	Vol. of gas, c.c.	Vol. of gas / Vol.of metal
Wire of .5 mm.	34	4.36	280.5	24.75	5.7	17	5.8	1.3	13	3.15	.72
Wire of 1 mm.	40	5.12	213.3	29.5	5.7	18	4.2	.82	15	2.75	.53
Wire of 2 mm.	40.5	5.2	108.8	25.5	4.9	22	10.4	2.0	19	7.15	1.3
Bar of 1 cm. (1)	38.6	5.0	22.0	4.15	.8	24	5.4	.54	21	5.15	.51
Bar of 1 cm. (2)	38.7	5.0	22.0	2.8	.56						
Plate of 1 mm. (1)	41.0	5.25	80	25.25	4.8	23	15.3	1.4	23	9.7	.91
Plate of 1 mm. (2)	41.5	5.32	80	38.50	5.3						
Filings of 1 cm. bar	46.0	5.9	very large	85.0	16.1	17	21.0	3.56	4	.5	.08

TABLE V.

No. 3.—Gas Analysis of First Series—Boudouard.

Nature of metal	Nature of determination	Vol. of gas, c.c.	Vol. of gas / Vol. of metal	CO_2	H_2	CO	N_2	Per cent. composition			
								CO_2	H_2	CO	N_2
Wire of .5-1 and 2 mm.	1. Heating to 300° twice, then 1100°	6.2	2.2	.52	2.0	3.5	.18	8.05	32.26	56.45	3.23
	2. Heating to 1100°..............	6.7	2.4	.12	2.66	2.84	1.08	1.8	39.7	42.4	16.1
Wire of .5 mm.	1. Heating to 300° once, then 1100°	9.0	1.8	1.58	3.67	3.53	.22	17.5	40.8	38.2	3.5
	2. Heating to 1100°..............	4.06	.8	.46	1.34	1.18	1.08	11.3	33.0	29.1	26.6
Wire of 1 mm.	1. Heating to 300° once, then 1100°	4.05	1.0	.51	1.85	1.62	.07	12.6	45.6	40.0	1.8
	2. Heating to 1100°..............	2.25	.56	.37	.94	.41	.53	16.4	41.8	18.2	23.6
Wire of 2 mm.	1. Heating to 300° once, then 1100°	15.5	2.0	2.6	2.62	10.28	.53	16.8	16.9	66.3	23.6
	2. Heating to 1100°..............	8.6	1.1	.66	2.66	4.91	.37	7.7	30.9	57.1	4.3
Bar of 1 cm...	1. Heating to 300° once, then 1100°	3.5	.7	.10	.82	2.28	.30	2.86	23.42	65.15	8.57
	2. Heating to 1100°..............	2.85	.57	.15	.72	1.57	.29	5.2	25.6	55.1	14.1
Plate of 1 mm.	1. Heating to 300° once, then 1100°	16.0	2.2	1.51	2.05	12.4	.04	9.4	12.8	77.5	.3
	2. Heating to 1100°..............	10.65	1.5	.51	3.16	6.72	.26	4.7	23.7	63.1	.25

TABLE V.

No. 4.—Gas Analysis of Second Series.—Boudouard.

Nature of metal	Nature of determination	Vol. of gas, c.c.	Vol. of gas	CO_2	H_2	CO	N_2	Per cent. composition			
			Vol. of metal					CO_2	H_2	CO	N_2
Wire of .5 mm.	1. Heating to 1100° C.	24.75	5.7	5.47	7.57	10.95	0.76	22.1	30.6	44.2	3.1
	2. Heating to 1100° C.	5.8	1.3	.48	2.64	1.02	1.66	8.3	45.5	17.6	28.6
	3. Heating to 1100° C.	3.15	.72	.27	1.68	.73	.47	8.5	53.1	23.1	15.3
Wire of 1 mm.	1. Heating to 1100° C.	29.5	5.7	6.54	4.43	18.03	.50	22.17	15.01	61.12	1.7
	2. Heating to 1100° C.	4.2	.82	.24	1.85	1.71	.60	5.7	39.3	40.7	14.3
	3. Heating to 1100° C.	2.73	.53	.23	1.75	.49	.26	8.4	64.1	17.9	9.6
Wire of 2 mm.	1. Heating to 1100° C.	25.5	4.9	3.68	5.72	15.88	.22	14.4	22.4	62.3	.9
	2. Heating to 1100° C.	10.4	2.0								
	3. Heating to 1100° C.	7.15	1.3	.26	2.37	4.26	.26	3.65	33.1	59.6	3.65
Bar of 1 cm. . .	1. Heating to 1100° C.	2.8	.56	.26	1.06	1.7	.04	3.65	37.8	60.7	1.5
	2. Heating to 1100° C.	5.4	.54	.2	1.78	3.42	.04	3.8	32.9	63.3	1.5
	3. Heating to 1100° C.	5.15	.51	.31	1.49	3.16	.19	6.0	28.9	61.3	3.8
Plate of 1 mm.	1. Heating to 1100° C.	28.5	5.3	3.61	5.74	18.79	.36	12.7	20.1	65.9	1.3
	2. Heating to 1100° C.	15.3	1.4	.81	4.34	9.85	.30	5.3	28.3	64.4	2.0
	3. Heating to 1100° C.	9.7	.91	.66	2.62	5.97	.45	6.8	27.0	61.6	4.6
Filings of 1 cm. Bar	1. Heating to 1100° C.	85	16.1	4.4	21.7	54.5	4.4	5.2	25.5	64.1	5.2
	2. Heating to 1100° C.	21	3.50	.76	7.47	11.95	.82	3.6	35.6	57.0	3.8
	3. Heating to 1100° C.	.5	.08				.82				

No. 5.—C. Contents—Boudouard.

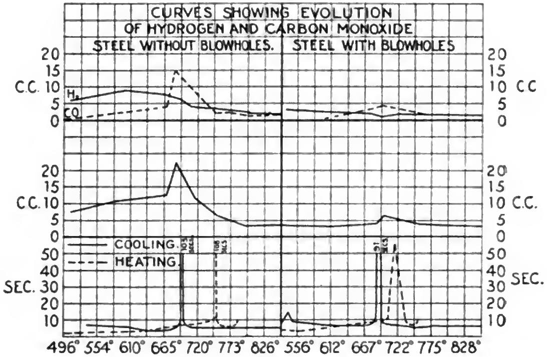
Nature of metal	Mass G.	C-start, G.	C-finish, G.	C-loss, G.	C. in gas, G.
Wire of .5 mm.	34	0.016	0.0060	0.01	0.0101
Wire of 1.0 mm.	40	.0296	.0132	.0164	.0185
Plate of 1.0 mm.	82.5	.1075	.0767	.0308	.0315
Filings.	46	.0450	.0230	.0220	.0384

No. 6.—Boudouard.

Nature of metal	Nature of determination	Mass G.	Vol. of gas, c.c.	Volume in c.c.				Weight in G.				Gas per cent. of metal				
				CO_2	H_2	CO	N_2	CO_2	H_2	CO	N_2	CO_2	H_2	CO	N_2	Sum
Wire of .5 mm.	Heat to 1100° C.	34	33.7	6.22	11.89	12.7	2.89	.012	.0011	.016	.0036	.035	.0032	.047	.0105	.0957
Wire of .5 mm.	Heat to 1100° C.	50	36.43	7.01	7.83	20.23	1.36	.014	.0005	.025	.0017	.035	.0017	.062	.004	.1029
Wire of .5 mm.	Heat to 1100° C.	82.5	78.75	5.08	17.4	53.46	2.81	.01	.0017	.067	.0035	.012	.0018	.081	.0042	.099
Filings.	Heat to 1100° C.	46	106	5.16	29.17	66.45	5.22	.01	.0026	.083	.0065	.021	.0056	.018	.0142	.02207

At the meeting[24] at which Goutal made public the above results Andrew C. J. Charlier read a report of some experiments he had conducted on the solubility of hydrogen in iron and steel. He asserted that ordinarily iron and steel would absorb hydrogen up to 25 volumes, but that, in the case of electrolytic iron, the proportion was increased to 100 volumes.

Thomas Baker[25] conducted a number of investigations on occluded gases with the following three-fold purpose: To ascertain the nature and volume of the gas evolved when steel was heated in a vacuum; to find the relation, if any existed, between the critical points of steel and the extent of evolution of gas; and to determine the part played by these gases in the production of blowholes.



Baker.

Baker used porcelain tubes very similar to those employed by Belloc and Boudouard. In connection with the use of these tubes, he made the observation that it was very difficult to obtain tubes which were impervious to gases above 900° C., as many as six often being tested before an air-tight one was secured. Before using his apparatus Baker made a number of blank determinations in order to determine whether or not any error would be introduced by the apparatus. When the tube was heated under a vacuum for three days, 1.29 c.c. of gas of the following composition was evolved:

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[24] *Seventh Inter. Cong. Appl. Chem.*, London, 1909.

[25] *Jour. of Iron and Steel Inst.*, Carn. Schol. Mem., 1909, 1, pp. 219-229; *Ibid.*, 1911, 3, pp. 249-259.

Gas	Percentage
Hydrogen	52.7
Carbon monoxide	7.8
Methane	20.9
Nitrogen	18.6
Total	100.00

The tube was then heated for nine days, the gas being drawn off and analyzed every three days. The analysis of the gas is given below:

	Volume c.c.	Per cent. CO_2	Per cent. H	Per cent. CH_4	Per cent. N
1st period	0.84	15.48	40.00	19.05	25.47
2d period	1.15	18.25	52.20	5.48	12.78
3d period	1.18	4.23	73.22	5.93	3.13
Total	3.17				

(To be continued.)

Valuable Clay Deposits in Louisiana. Anon. (*U. S. Geological Survey Press Bulletin,* No. 349, December, 1917.)—The clays of Louisiana have not received a great deal of attention for two reasons. As the principal industry of Louisiana is agriculture, the demand for clay products within the state has not been great; furthermore, most of the local needs for structural material have been supplied by its large and valuable timber resources. Some structural materials have been manufactured from clay in the vicinity of some of the large cities, but Louisiana in 1915 produced a little less than 0.25 per cent. (in value) of the total clay products of the United States.

In a paper entitled "Louisiana Clays," by George C. Matson, just issued as Bulletin 660-E of the United States Geological Survey, Department of the Interior, clays obtained in each of the principal geologic formations of the state are described, and the results of tests made by the Bureau of Standards are given. The paper shows that there are in Louisiana considerable deposits of clay suitable for making common brick, draintile, hollow brick, and the simpler shapes of fireproofing.

A copy of this paper may be obtained by addressing a request for it to the Director, U. S. Geological Survey, Washington, D. C.

OUTLINE OF COLLOID CHEMISTRY.—II.*

BY

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ADSORPTION FROM SOLUTION AND COALESCENCE.

ADSORPTION FROM SOLUTION BY SOLID.

SELECTIVE adsorption from a solution by a solid may show itself by relatively more of the dissolved substance being adsorbed than of the solvent, or by relatively less being adsorbed. Both cases are known, but the first one is the more interesting. The decolorizing action of charcoal[1] has been known since 1791. In 1874 Böttger[2] pointed out that infusorial earth will remove all the color from aqueous solutions of some aniline dyes. The adsorption of dyes by hydrous alumina, stannic oxide, and other mordants, as they are called, is of great importance. Here, as in all other cases, the adsorption is selective, some dyes being taken out and others not.[3] Red phosphorus will decolorize a dilute solution of iodine in carbon bisulphide.[4] Hatschek[5] points out that iodides cannot be shown to be present in sea-water by any of the usual tests, and that we owe our supply of iodine to the adsorption of iodides by certain sea-weeds. When making density determinations by weighing a solid in a solution, an error may be introduced because of the solid adsorbing some of the salt.[6] According to Skey,[7] antimony and arsenic can be removed from solutions of their oxides or chlorides in strong hydrochloric acid (with a little tartaric acid in the case of antimony) so that neither of them can be detected by Reinsch's test, though both were easily detected before the adsorption.[8] In 1845

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* Based on a paper presented at the meeting of the Section of Physics and Chemistry held Thursday, January 11, 1917.

[1] Cf. Ostwald, "Lehrbuch allgem. Chemie," 1, 1093 (1891).

[2] *Jour. Chem. Soc.*, **28**, 170 (1875).

[3] Cf. Davison, *Jour. Phys. Chem.*, **17**, 737 (1913).

[4] Sestini, *Gazz. chim. ital.*, 1, 323 (1871).

[5] "An Introduction to the Physics and Chemistry of Colloids," 6 (1913).

[6] Thoulet, *Comptes rendus*, **99**, 1071 (1884).

[7] *Chem. News*, **17**, 157 (1868); **36**, 6 (1877).

[8] See also Lockemann and Paucke, *Zeit. Kolloidchemie*, **8**, 273 (1911).

Yorke[9] noted the adsorption of lead oxide by filter-paper, while Müller[10] and Weiske[11] have shown that filter-paper takes up such appreciable quantities of barium, strontium, and calcium hydroxides that dilute solutions should not be filtered if they are to be used for quantitative work.

A special phenomenon in connection with adsorption by filter-paper has been studied by Bayley,[12] Lloyd,[13] Gordon,[14] and others. If a drop of salt solution be allowed to fall on a piece of filter-paper the solution will tend to spread. If the salt is adsorbed very strongly it will not spread and we get a relatively wide water-ring. If the salt is not much adsorbed, it will spread out as far as the water. If a strip of filter paper be dipped into a solution we get a similar phenomenon; the water will rise much farther than the salt if the latter is adsorbed strongly. Gordon found that with a M/40 $CuSO_4$ solution the water rose about 9.2 cm. in half an hour and the copper salt only 5.5 cm. With a M/2 solution the copper salt rose 9.2 cm., and so did the water. Ordinary ink shows the phenomenon well with blotting-paper.

Leighton[15] has determined the adsorption of caustic soda, hydrochloric acid, sulphuric acid, and phosphoric acid by purified absorbent cotton. These experiments were interesting in two ways. In the first place, they showed that no compounds were formed. In the second place, data were obtained showing the possible error when determining adsorption. The usual method is to shake a known solution with a weighed amount of the adsorbing solid, pipette off some of the supernatant liquid, and analyze. The amount of adsorption is calculated from the decrease in concentration. This calculation is accurate only in case no liquid is taken up by the solid adsorbing agent. If the cotton adsorbed the alkali and the water in the same ratio in which they occurred in the solution there would be no change in the concentration of the solution and the apparent adsorption would be zero. To avoid this error, Leighton centrifuged the cotton for an hour in a centrifugal rotating about 4000 revolutions per minute, and then analyzed the cotton This direct or "gravimetric" method will give too high adsorptions unless the centrifuging removes all the unadsorbed solution. On the other hand, the indirect or "titration" method gives too low results unless no water is adsorbed by the cotton at all. Since this last is not true, the results by the titration method are necessarily wrong with cotton, while the results by the gravimetric method may be right. The differences between the two methods may be quite considerable. With a solution of 200 grams NaOH per liter Leighton found an adsorption of 0.27 grams NaOH per gram cotton by the titration method, and of 0.75 gram NaOH by the gravimetric method. The true adsorption lies between these two values. Leighton's data for NaOH are given in Table I.

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[9] *Mem. Chem. Soc.*, **2**, 399 (1845).

[10] *Jour. prakt. Chem.*, **83**, 384 (1861).

[11] *Jour. Chem. Soc.*, **30**, 662 (1876).

[12] *Ibid.*, **33**, 304 (1878).

[13] *Chem. News*, **51**, 51 (1885).

[14] *Jour. Phys. Chem.*, **18**, 337 (1914).

[15] *Ibid.*, **20**, 32, 188 (1916).

TABLE I.

Volume of solution = 100 c.c.
Weight of cotton = about 1.0 g.
Time of run = 3 hours.

Solution grams NaOH per liter	Grams NaOH adsorbed per gram cotton		Solution grams NaOH per liter	Grams NaOH adsorbed per gram cotton	
	Gravimetric	Titration		Gravimetric	Titration
474	0.916	....	230	0.664	....
450	.....	0.28	212	0.662	....
427	0.887	....	210	.....	0.19
415	0.875	....	190	0.594	....
400	.....	0.27	189	0.579	....
379	0.846	....	184	0.572	....
350	.....	0.27	175	.....	0.12
323	0.782	....	140	.....	0.08
300	.....	0.27	138	0.461	....
276	0.733	....	125	0.433	....
275	.....	0.25	90	.....	0.01
231	0.665	....	40	.....	0.0

Osaka[16] has made some experiments on the adsorption of potassium and sodium salts by blood charcoal. The charcoal takes up about 85 per cent. of its weight of water when suspended in saturated water vapor at 25°. If no account is taken of this fact a large error may be introduced. When allowance was made for the amount of adsorbed water it was found that the adsorption decreased in the order $I > No_3 > Br > Cl > SO_4$. The potassium salts are adsorbed more strongly than the corresponding sodium salts. The numerical values are given in Table II. The percentage adsorptions for normal solutions of KI, KNO_3, KBr, KCl, and K_2SO_4 are approximately 28, 16, 14, 7, and 5 respectively.

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[16] *Mem. Coll. Sci. Kyoto*, 1, 257 (1915).

An interesting and important case of selective adsorption has been worked out by Lloyd. From fuller's earth he has prepared a hydrous aluminum silicate [17] which adsorbs alkaloids. It has been suggested that the material be called Lloyd's reagent.

TABLE II.

Adsorption of Salts (Milligrams and Milligram Equivalents) per Gram Blood Charcoal.

Concentration of solution in gram equivalent per liter.	Salt adsorbed by one gram charcoal		Concentration of solution in gram equivalent per liter	Salt adsorbed by one gram charcoal	
	Milligram	Milligram equivalent		Milligram	Milligram equivalent
	Potassium sulphate			Sodium sulphate	
1.010	51.4	0.59	1.068	40.5	0.57
0.830	45.1	0.52	0.933	37.4	0.53
0.673	37.0	0.42	0.753	31.9	0.45
0.509	29.3	0.34	0.583	25.5	0.36
	Potassium chloride			Sodium chloride	
0.966	68.6	0.92	0.998	47.4	0.81
0.765	50.8	0.68	0.896	44.9	0.77
0.562	41.8	0.56	0.697	35.3	0.60
0.479	33.2	0.45	0.597	29.0	0.49
	Potassium nitrate			Sodium nitrate	
0.977	151.2	1.50	0.978	116.3	1.37
0.817	129.9	1.28	0.816	107.6	1.27
0.654	112.7	1.11	0.647	99.4	1.03
0.491	87.7	0.87	0.484	69.6	0.82
	Potassium iodide			Potassium bromide	
0.967	277.9	1.67	0.970	139.2	1.17
0.833	250.8	1.51	0.717	98.1	0.82
0.622	207.4	1.25	0.526	75.7	0.64
0.464	167.8	1.01	.....	.....	....

Carey Lea [18] has shown that silver idoide adsorbs iodine strongly. It is probably this adsorption which makes silver iodide photographic emulsions apparently less sensitive than the silver bromide emulsions. If so, it should not be hard to overcome that difficulty. Reinders [19] has found that silver chloride crystals contain adsorbed gelatine when crystallizing from an ammoniacal solution to which gelatine has been added. This fact is of great importance for the theory of the photographic emulsion.[20] Much other work on adsorption by crystals is to be found in the papers by Marc.[21] The selective nature of the adsorption is shown by the fact that barium sulphate is said to carry down large amounts of barium nitrate and only small quantities of barium chloride.[22] These experiments should be repeated.

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[17] Waldbott, *Jour. Am. Chem. Soc.*, **35**, 837 (1913).

[18] *Am. Jour. Sci.* (3), **33**, 492 (1887).

[19] *Zeit. phys. Chem.*, **77**, 696 (1911).

On or just back of the beaches at Galveston, Nantucket, and elsewhere there are wells of fresh water, the levels of which correspond approximately with the ocean level. Many people believe that the water in these wells comes from the sea and that the salts have been removed in some mysterious way. Unfortunately this is not true. The water comes from inland, but is backed up by the ocean and does not flow off so rapidly as it otherwise would. If for any reason the outward flow is checked for a sufficient time, the salt from the ocean does work back into the wells. This has been noticed at Galveston when excessive amounts of water have been pumped from the wells.

THE ADSORPTION ISOTHERM.

In all cases which have been studied quantitatively, the form of the adsorption isotherm is similar to that obtained for the adsorption of gases by solids. Consequently an equation of the same type will represent both sets of phenomena. For solutions we write the equation where x is the amount adsorbed by m

$$(x/m)^n = k\,c$$

units of the solid adsorbing agent, c is the concentration of the solution, and n is not necessarily an integer, though experimentally never less than unity. The approximate accuracy of the formula is shown in Freundlich's data,[23] Tables III–V. Other adsorption formulas have been proposed, or discussed by Freundlich,[24] McBain,[25] Schmidt,[26] Georgievics,[27] and others,[28] but no formula is strictly accurate, and the simplest one seems the best for the time being. If the curves really bend round parallel to the axis of ordinates, the simple formula is necessarily wrong.

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[20] Bancroft, *Jour. Phys. Chem.*, **17**, 93 (1913).

[21] *Zeit. phys. Chem.*, **61**, 385 (1908); **67**, 470 (1909); **68**, 104 (1909); **73**, 685 (1910); **75**, 710 (1911).

[22] Mitscherlich, *Liebig's Ann.*, **44**, 192 (1842).

[23] "Kapillarchemie," 147 (1909).

[24] *Zeit. phys. Chem.*, **57**, 385 (1907); **59**, 284 (1907).

[25] *Jour. Chem. Soc.*, **91**, 1683 (1910).

[26] *Zeit. phys. Chem.*, **74**, 689 (1910); **77**, 641 (1911); **78**, 667 (1912); **91**, 103 (1916).

[27] *Ibid.*, **83**, 269 (1914).

[28] Marc, *Zeit. phys. Chem.*, **51**, 641 (1913); Dietl, *Monatsheft für Chemie*, **35**, 784 (1914); Trümpler, *Zeit. Kolloidchemie*, **15**, 10 (1914).

TABLE III.

Distribution of Acetic Acid between Water and Blood Charcoal.

$(x/m)^n = kc$

$n = 2.35$; $\log k = 0.98$

c in mols per liter; x/m in millimols per gram charcoal.

c	x/m found	x/m calc.	$\log k$
0.0181	0.467	0.474	0.966
0.0309	0.624	0.623	1.029
0.0616	0.801	0.798	0.984
0.1259	1.11	1.08	1.006
0.2677	1.55	1.49	1.030
0.4711	2.04	1.90	1.055
0.8817	2.48	2.48	0.981
2.785	3.76	4.04	0.906

TABLE IV.

Distribution of Bromine between Water and Blood Charcoal.

$(x/m)^n = kc$

$n = 2.4$; $\log k = 0.974$

c in millimols per liter; x/m in millimols per gram charcoal.

c	x/m found	x/m calc.	$\log k$
0.92	2.07	2.09	0.965
2.59	3.10	2.96	1.032
6.69	4.27	4.10	1.028
17.08	5.44	5.64	0.930
29.75	6.80	6.80	0.974

TABLE V.

Distribution of Benzoic Acid between Water and Blood Charcoal.

$(x/m)^n = kc$

$n = 2.53$; $\log k = 2.32$

c in millimols per liter; x/m in millimols per gram blood charcoal.

c	x/m found	x/m calc.	$\log k$
6.18	0.437	0.445	2.299
25.00	0.780	0.776	2.329
53.13	1.04	1.04	2.318
117.73	1.44	1.43	2.330

In Table VI are given a list of a few of the systems which have been studied quantitatively. The values for *n* have undoubtedly been rounded off in most cases. The fact that we get a smooth curve with water, iodine, and starch shows that there is no definite compound, starch iodide.

TABLE VI.

Solvent	Solute	Solid	*n*	Observer
Alcohol	Iodine	Charcoal	4	Schmidt [1]
Benzene	Iodine	Charcoal	4	Schmidt [1]
Water	Acetic acid	Charcoal	2	Schmidt [1]
Water	Succinic acid	Charcoal	2	Schmidt [1]
Water	Oxalic acid	Charcoal	10	Schmidt [1]
Water	Potassium chloride	Silicic acid	1	
Water	Potassium chloride	Stannic oxide	1	Van Bemmelen[2]
Water	Potassium chloride	Charcoal	1	Lachs and Michaelis [3]
Water	Sulphuric acid	Caseine	1.95	Van Slyke [4]
Water	Indigo carmine	Silk	2	Georgievics [5]
Water	Methylene blue	Cellulose	2	Georgievics [5]
Water	Iodine	Starch	5	Küster [6]
Water	Alizarine	Chromic oxide	3	Biltz [7]
Water	Milk sugar	Charcoal	4.5	Wagner[8]
Water	Cane sugar	Charcoal	8.2	Wagner[8]
Water	Picric acid	Silk	2.7	Walker and Appleyard[9]

[1] *Zeit. phys. Chem.*, **15**, 56 (1894).
[2] *Zeit. anorg. Chem.*, **23**, 113 (1900).
[3] *Zeit. Elektrochemie*, **17**, 2 (1911).
[4] *Am. Chem. Jour.*, **38**, 383 (1897).
[5] *Sitzungsber. Akad. Wiss. Wien.*, **103**, ii b, 589 (1894); **104**, ii, b, 309 (1895); *Zeit. Farbenindustrie*, **2**, 253 (1903).
[6] *Liebig's Ann.*, **283**, 364 (1891).
[7] *Ber. deutsch. chem. Ges.*, **38**, 4143 (1905).
[8] *Zeit. Kolloidchemie*, **8**, 126 (1911).
[9] *Jour. Chem. Soc.*, **69**, 1334 (1896).

ABNORMAL ADSORPTION.

Cameron and Patten [29] find that the distribution of gentian violet between soils and water, or of eosine between quartz and water, can be represented fairly well by exponential formulas; but that flocculation or coarsening of the adsorbing medium is apparently a disturbing factor. That flocculation actually does take place had been shown by Patten [30] in a special set of experiments on quartz flour and dyes. A still more striking case of flocculation and consequent change of adsorption was studied by Lottermoser and Rothe [31] in the adsorption of potassium iodide by silver iodide. For concentrations of potassium iodide up to about N/300 the exponential formula holds fairly well, the exponential factor being a little over 13. Beyond this concentration the amount of adsorption actually decreases with increasing concentration in the water phase. The silver iodide becomes denser and more granular and shows signs of crystallization. On the other hand, silver nitrate is adsorbed by silver iodide without producing this change within the concentrations studied. The exponential factor is 2 for silver nitrate. Freundlich and Schucht [32] found that amorphous mercuric sulphide changes over spontaneously into a crystalline form and then has a decreased power of adsorbing dyes. The adsorption of eosine by hydrous copper oxide varies with changes in the cupric oxide.[33] The cases of abnormal adsorption reported by Evans are apparently due to analytical errors.[34]

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[29] *Jour. Phys. Chem.*, **11**, 581 (1907).
[30] *Trans. Am. Electrochem. Soc.*, **10**, 67 (1906).
[31] *Zeit. phys. Chem.*, **62**, 359 (1908).

In 1899 Lagergren [35] reported the negative adsorption of some chlorides and of ammonium bromide by charcoal, the solution becoming more concentrated after being shaken with the charcoal. Quite recently Osaka [36] found that sodium nitrate, potassium bromide, potassium iodide, and potassium nitrate are adsorbed positively by blood charcoal, while sodium chloride, sodium sulphate, and potassium sulphate are apparently adsorbed negatively. With sodium sulphate the increase in concentration was about one per cent., and was less than that with the other salts. Mathieu [37] observed negative adsorption with a number of dilute solutions when adsorbed by porous plates, membranes, or capillary tubes. With normal solutions the concentrations in the capillary tubes were often only tenth-normal. The difference in concentration increases with decreasing radius of the capillary tubes, and Mathieu considers it quite possible that with very fine tubes water alone would be adsorbed, a conclusion which, as Mathieu himself points out, is of distinct importance for the theory of semipermeable membranes.[38] If this conclusion is true and general, it accounts for the results of Bigelow[39] and of Bartell,[40] who found that osmotic phenomena appeared in porous cups when the pores were sufficiently fine or were clogged sufficiently. It is clear that we can get osmotic phenomena in two distinct ways, depending on whether we have a continuous film or a porous one.[41] In the case of a continuous film it is essential that the solvent shall dissolve in the membrane and that the solute shall not. Since the permeability is not dependent on adsorption, there is no reason why there should be any fundamental difference between the adsorption of a solute which does pass through the membrane and of one which does not pass through. If we have a porous film, we get osmotic phenomena only in case the pore walls adsorb the pure solvent, and the diameter of the pores is so small that the adsorbed film of pure solvent fills the pores full. Under these circumstances the dissolved substance can not pass through the membrane unless adsorbed by the latter. There is therefore an important difference between a solute which does pass through a porous membrane and one that does not, in that the first is adsorbed by the membrane and the second is not.

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[32] *Ibid.*, **85**, 660 (1913).

[33] Gilbert, *Jour. Phys. Chem.*, **18**, 592 (1914).

[34] Murray, *Ibid.*, **20**, 621 (1916).

[35] Freundlich, "Kapillarchemie," 165 (1909).

[36] *Mem. Coll. Sci. Kyoto*, **1**, 257 (1915).

[37] *Drude's Ann.*, **9**, 340 (1902).

[38] Cf. Trouton, *Brit. Assn. Reports*, **84**, 288 (1914).

Kahlenberg[42] has shown that benzene, toluene, and pyridine pass through a rubber membrane very readily, while water does not. This is perfectly natural on the assumption that these liquids dissolve in rubber, but on the basis of pores it is hard to understand why water should not pass through. One might cite the case of the oiled sieve and say that water does not wet rubber, but water does wet rubber. The case of trichloracetic acid is also interesting. When dissolved in benzene it passes readily through a rubber membrane, whereas it passes very slowly when dissolved in water. This is as it should be if we are dealing with solution, but it is hard to explain if we are dealing with adsorption. While nothing is proved, I am inclined to think that a rubber membrane is not a porous one in the sense that Bartell's clogged plate is, and I believe, therefore, that, when a rubber film acts as a semipermeable membrane, the solvent dissolves in the rubber and passes through it essentially in that way. There are no satisfactory data in regard to the copper ferrocyanide membrane, but it seems better for the present to consider it as like the rubber membrane.

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[39] *Jour. Am. Chem. Soc.*, **29**, 1576, 1675 (1907); **31**, 1194 (1909).

[40] *Jour. Phys. Chem.*, **15**, 659 (1911); **16**, 318 (1912); *Jour. Am. Chem. Soc.*, **36**, 646 (1914); **38**, 1029, 1036 (1916).

[41] Bancroft, *Jour. Phys. Chem.*, **21**, 441 (1917).

[42] *Jour. Phys. Chem.*, **10**, 141 (1906).

REVERSIBILITY OF EQUILIBRIUM.

To be certain that the equilibrium represented by the adsorption isotherm is a reversible one, it should be reached from both sides. As a rule, that is not done, but Freundlich[43] has made a couple of experiments to show that the same end-point is actually reached. For the distribution of acetic acid between charcoal and water, he obtained a concentration in the water of N/16.47 when he shook one gram of charcoal with 100 c.c. of N/14.53 solution, and a concentration of N/16.49 when he shook one gram of charcoal with 50 c.c. of a N/7.27 solution and then added 50 c.c. water. For the distribution of benzoic acid between charcoal and benzene, a similar proceeding with other concentrations gave him the two final values of N/8.5 and N/8.48. In some cases equilibrium is reached very rapidly from both sides, and in others not.[44] While the adsorption equilibrium is theoretically a reversible one, there are conditions under which there may be apparent or actual irreversibility. If charcoal takes a dye out of solution to such an extent as to decolorize the water practically, no amount of washing with water will give a colored solution, even though dye is being taken out all the time.[45] In this case the adsorption is strictly reversible, and the difficulty was in the interpretation of the results.

There is one experiment which I always like to try, because it proves something whichever way it goes. A solution of iodine in water is shaken with bone-black, filtered, and tested with starch paste. If the colorless solution does not turn the starch blue, the experiment shows how completely charcoal extracts iodine from aqueous solution. If the starch turns blue, the experiment shows that the solution, though apparently colorless, still contains iodine, which can be detected by means of the sensitive starch test.

If the adsorbing substance changes through agglomeration, crystallization, or in any other way, its specific adsorbing power will change, and the adsorbed substance will be held either more or less firmly, as the case may be. Some instances of this have already been cited under abnormal adsorption. The adsorbed substance may also change on standing or on heating, in which case we shall have an apparent irreversibility, though we are really dealing, as before, with a new reversible equilibrium. This case occurs very frequently in dyeing.[46]

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[43] "Kapillarchemie," 148 (1909).

[44] Freundlich, *Zeit. phys. Chem.*, **57**, 388 (1906); Ostwald, *Lehrbuch allgem. Chemie*, **1**, 1096 (1891); Schmidt, *Zeit. phys. Chem.*, **74**, 708 (1910).

[45] Freundlich and Neumann, *Ibid.*, **67**, 538 (1900).

SPECIFICITY OF ADSORPTION.

Since adsorption is essentially specific, the amount of adsorption will necessarily vary with the nature of the adsorbing agent, the liquid, and the substance to be adsorbed. In illustration of this, Freundlich [47] cites the experiments of Wöhler, Pluddeman and Wöhler [48] to the effect that charcoal and ferric oxide adsorb benzoic acid about ten times as strongly as acetic acid, while chromium oxide adsorbs the two acids about equally, and platinum black adsorbs acetic acid a little, but benzoic acid practically not at all. All salts seem to show distinct adsorption for their own ions. Thus silver bromide adsorbs silver nitrate or potassium bromide, but not potassium nitrate. Charcoal adsorbs both acid and basic dyes. Alumina takes up many acid dyes readily and not the basic dyes; silica and tannin adsorb the basic dyes more readily than acid dyes. Wool adsorbs many dyes strongly without a mordant, and cotton relatively few. What is known as Schulze's law [49] is that the power of active ions to precipitate colloidal solutions is a function of its valence, or of the number of electrical charges which it carries. Since the precipitating power, in the cases studied by Schulze, depends on the degree of adsorption, it follows that, in so far as Schulze's law holds, a trivalent ion will be adsorbed more strongly than a bivalent ion, and the latter more strongly than a univalent one. Schulze's law is merely a first approximation.[50] Everybody recognizes that hydrogen and hydroxyl ions are not to be classed with the other univalent ions, because they are usually adsorbed much more strongly,[51] and everybody recognizes that there are other exceptions. In case of doubt, it is generally safe to assume that an ion of higher valence will be adsorbed more strongly than one of lower valence, but it is a mistake to consider this so-called law as anything more than a guide. For instance, Osaka [52] found that charcoal adsorbed potassium salts in the following order when the salts were present in equivalent concentrations: $KI > KNO_3 > KBr > KCl > K_2SO_4$, from which it follows that, for equivalent concentration, the sulphate ion is adsorbed the least of all. If we were to compare molecular concentrations the sulphate ion would be adsorbed as strongly as the bromide ion, but less than the nitrate or the iodide ion. Davis [53] found that the order of adsorption of iodine from different liquids was not the same with different kinds of charcoal. With animal charcoal there was decreasing adsorption in the order: chloroform, alcohol, ethyl acetate, benzene, and toluene; with sugar charcoal the adsorption decreased in the order: chloroform, toluene, ethyl acetate, benzene, and alcohol; whereas for cocoanut charcoal the order was toluene, chloroform, benzene, alcohol, and ethyl acetate. There are at least two factors governing the effect of the solvent. The more soluble the dissolved substance is in a given solvent, the less readily will it be adsorbed, provided we can neglect the adsorption of the solvent itself by the solid. There are many illustrations of this, but one will suffice. Charcoal will decolorize aqueous solutions of iodine or of methyl violet, but alcohol will extract the color from the charcoal. The solubility cannot be the sole factor, however, because then the solvents could always be arranged in the same order for the same solute, regardless of the nature of the adsorbing agent. This is disproved absolutely by the experiments of Davis. One other factor is the adsorption of the solvent by the adsorbing agent. This factor was not taken into account at all by Davis, whose data are therefore not sufficient to enable us to tell whether there are other factors to be considered.

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[46] Lake, *Jour. Phys. Chem.*, **20**, 761 (1916).

[47] "Kapillarchemie," 155 (1909).

[48] *Zeit. phys. Chem.*, **62**, 664 1908).

[49] Schulze, *Jour. prakt. Chem.* (2), **25**, 43 (1882); **27**, 320 (1884).

[50] Bancroft, *Jour. Phys. Chem.*, **19**, 363 (1915).

[51] Freundlich, "Kapillarchemie," 354 (1909).

In so far as adsorption is accompanied by an evolution of heat, the amount of adsorption must decrease with rising temperature. This is found to be the case experimentally, but the change is often a very small one. In some cases there is an apparently large increase in adsorption with rising temperature. Thus wool takes up very little acid violet at 20° and a great deal at about 95°. Experiments showed[54] that this adsorption is not reversible, for the acid violet adsorbed at the higher temperature cannot be washed out to any extent at 20°. After adsorption the dye agglomerates or changes so that it becomes practically insoluble, and consequently the wool takes up more dye.

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[52] Osaka, *Mem. Coll. Sci. Kyoto*, **1**, 267 (1915).

[53] *Jour. Chem. Soc.*, **91**, 1682 (1907).

ADSORPTION OF SEVERAL SOLUTES.

Some years ago there was a widespread rumor that strychnine had been added to a certain breakfast cereal to make it more appetizing. The report was false and not even new, for in 1852 it was alleged that strychnine was being added to certain English pale ales. In order to show that strychnine could be detected in beer if present, Graham and Hofmann[55] shook two ounces of animal charcoal with half a gallon of beer to which ½ grain of strychnine had been added. The strychnine was removed practically completely by the charcoal, and was extracted from that with alcohol and identified.

Skey[56] reports that dilute sulphuric acid can be freed from traces of nitric acid by shaking with charcoal, while concentrated sulphuric acid cannot be. Dudley[57] showed that the rank and disagreeable odor of raw whiskey can be removed by leaching through charcoal. Schmidt[58] has studied the simultaneous adsorption of iodine and acetic acid by charcoal from solutions in water and in ethyl acetate. With both solvents less of each substance was adsorbed than if the other had not been present. Schmidt believes that this is general, but this statement is undoubtedly too broad, though it holds in many cases. Freundlich and Masius[59] studied the adsorption of pairs of organic acids and obtained results similar to those of Schmidt. They also found that the acid, which is adsorbed more, is displaced the less when the two acids are present in the solution. These experiments throw light on Skey's experiments. With increasing relative concentration of sulphuric acid, we should expect an increasing displacement of nitric acid from the charcoal, which is what actually occurred. Lachs and Michaelis[60] found that caustic potash cut down very much the adsorption of potassium chloride by charcoal from water. In other words, the presence of the strongly adsorbed hydroxyl ion decreased the adsorption of the chloride very much. They also found that if sulphuric acid is added in small amounts to the chloride solution the adsorption of chloride ion is increased markedly. This is in accord with the results of Osaka,[61] that potassium chloride is adsorbed more than potassium sulphate, sodium chloride than sodium sulphate, and, presumably, hydrochloric acid than sulphuric acid.

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[54] Lake, *Jour. Phys. Chem.*, **20**, 761 (1916).

[55] *Jour. Chem. Soc.*, **5**, 173 (1853).

[56] *Chem. News*, **17**, 217 (1886).

[57] *Jour. Am. Chem. Soc.*, **30**, 1784 (1908).

[58] *Zeit. phys. Chem.*, **74**, 730 (1910).

[59] "Van Bemmelen Gedenkboek," 88 (1910).

Thorium salts cut down the adsorption of uranium X by charcoal,[62] and acetone and acetic acid decrease the adsorption of grape-sugar by charcoal,[63] but albumin and acetone have no effect each on the other, nor does one acid dye apparently displace another on wool or silk.[64]

CHEMICAL ACTION.

Selective adsorption connotes the possibility of chemical decomposition as a result of adsorption.[65] If a given solid adsorbs a base more strongly than an acid, for instance, there will be a tendency for the salt to hydrolyze, the base being then adsorbed to a greater extent than the acid. Theoretically there is always some hydrolysis even with sodium chloride and water, according to the equation,

$$\mathrm{Na}^{\cdot} + \mathrm{Cl}' + \mathrm{H_2O} \rightleftharpoons \mathrm{Na}^{\cdot} + \mathrm{OH}' + \mathrm{H}^{\cdot} + \mathrm{Cl}'$$

but this reaction does not run far, because caustic soda and hydrochloric acid are strong electrolytes, and we cannot have a high simultaneous concentration of hydrogen and hydroxyl ions. If the caustic soda is removed by adsorption, either of hydroxyl ion or of undissociated sodium hydroxide, the hydrolysis will go farther. How complete the hydrolysis will be depends on the degree to which the base is adsorbed and on the strength of the unadsorbed acid. Any acid will tend to react with adsorbed caustic soda, but the tendency will be greater the stronger the acid. We thus see that a neutral solution will become acid if shaken with a solid which adsorbs the base more strongly than the acid, that it will become alkaline if the solid adsorbs the acid much more strongly than the base, and that it will remain neutral in case the solid does not adsorb either base or acid at all, or in case it adsorbs the two in practically equivalent quantities. The amount of base or acid taken up from a salt solution will be greater the weaker the unadsorbed acid or base. The experiments of Liebermann[66] show clearly that the decomposition by charcoal is greater with salts of weak acids. Freundlich and Masius[67] have studied the adsorption of aniline benzoate and aniline acetate by charcoal. It so happens that aniline is adsorbed less strongly than benzoic acid by charcoal and more strongly than acetic acid. From a solution of aniline benzoate, therefore, charcoal adsorbs relatively more benzoic acid than aniline, while more aniline than acetic acid is adsorbed from an aniline acetate solution. Skraup[68] dipped filter-paper into a lead acetate solution and found that the acetic acid rose much higher than did the lead, which we know to be adsorbed strongly.[69]

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[60] *Zeit. Elektrochemie*, **17**, 1 (1911).

[61] *Mem. Coll. Sci. Kyoto*, **1**, 267 (1915).

[62] Freundlich and Kaempfer, *Zeit. phys. Chem.*, **90**, 681 (1915).

[63] Rona and Michaelis, *Biochem. Zeit.*, **16**, 499 (1909).

[64] Lake, *Jour. Phys. Chem.*, **20**, 761 (1916).

[65] Bancroft, *Ibid.*, **18**, 5 (1914).

The becoming acid or alkaline of a solution is not necessarily connected with any hypothetical acidity or alkalinity of the adsorbing substance. If fuller's earth be shaken with water and then filtered, the filtrate is neutral to litmus paper[70] or phenolphthalein, showing that no soluble base or acid is present. If fuller's earth be shaken with a sodium chloride solution and filtered, the filtrate is acid to litmus or to phenolphthalein. This is because fuller's earth has adsorbed the base. If one presses litmus paper against moistened fuller's earth, the litmus paper turns red, and if one adds fuller's earth to a fairly alkaline solution of phenolphthalein, the red color disappears. This is not because fuller's earth is acid, but because it takes the base from the sodium chloride, the litmus, or the phenolphthalein. Caseine is practically insoluble in pure water, and the filtrate is neutral to litmus paper. If moistened litmus paper be pressed against caseine, the latter adsorbs alkali from the paper, which, of course, turns red. The adsorption of alkali is so marked that caseine will set free carbon dioxide from carbonates and bicarbonates. It is not surprising, therefore, that people have considered caseine as an acid and have not perceived that the setting free of carbon dioxide is the result of selective adsorption. The bearing of this on the question of soil acidity has been discussed by Cameron.[71] A statement of the other side of the question has been given by Truog.[72]

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[66] *Sitzungsber. Akad. Wiss. Wien*, **74**, 331 (1876).

[67] "Van Bemmelen Gedenkboek," 100 (1910).

[68] *Zeit. Kolloidchemie*, **6**, 253 (1910).

[69] Yorke, *Mem. Chem. Soc.*, **2**, 399 (1845).

[70] Cf. Cameron, *Jour. Phys. Chem.*, **14**, 400 (1910).

Silk has such a marked selective adsorption for rosaniline (magenta) that it will not only decompose the hydrochloride, leaving the acid behind, but will also convert the carbinol base back into the color base in presence of an excess of ammonia,[73] the silk being dyed red from a colorless ammoniacal solution. This is the more remarkable because the free color base is instable and cannot be isolated in a pure state. This makes it seem certain that silk stabilizes the free color base. Another similar instance is the mordanting of wool with copper salts, coloring it green. This green does not change to black when the wool is heated to boiling, though hydrous copper oxide by itself changes very readily. Blucher and Farnau[74] have extended Tommasi's[75] experiments on the stabilization of hydrous copper oxide by manganese salts and find that a number of other metallic hydroxides are also effective. Bayliss[76] has obtained results, which indicate that alumina stabilizes the free acid of Congo red, and Schaposchnikoff and Bogojawlevski[77] have isolated this metastable form by allowing the pyridine salt to effloresce. Reference has already been made to the stabilization of a higher iron oxide by iron in the case of passive iron.

In the case of dyeing with acid or basic dyes we have an admirable illustration of the fact, first recognized by Lachs and Michaelis[78] and by Estrup,[79] that an anion is more readily adsorbed in presence of a readily adsorbed cation, and a cation in presence of a readily adsorbed anion. In an acid dye the color group is in the acid radical, and in a basic dye it is in the basic radical. An acid dye will therefore be taken up more readily in an acid solution than in a neutral solution, and will be taken up least in an alkaline solution. A readily adsorbed anion will decrease the amount of dye taken up, and a readily adsorbed cation will increase the amount of dye taken up. With a basic dye the reverse will be true. The dye will be taken up most readily in an alkaline solution, but may be taken up in a neutral or acid solution. A readily adsorbed cation will cut down the adsorption of the dye, and a readily adsorbed anion will increase it.[80] These generalizations appear to hold in all the cases studied so far.[81] Substantive dyes form colloidal solutions, and the question of stability is an important one.

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[71] *Jour. Phys. Chem.*, **14**, 399 (1910).

[72] *Ibid.*, **20**, 457 (1916).

[73] Jacquemin, *Comptes rendus*, **82**, 261 (1876); see also Mills, *Jour. Chem. Soc.*, **35**, 27 (1879); Fortuyn, *Zeit. phys. Chem.*, **90**, 236 (1915).

[74] *Jour. Phys. Chem.*, **18**, 629 (1914).

[75] Tommasi, *Bull. Soc. chim. Paris* (2), **37**, 197 (1882); *Comptes rendus*, **99**, 37 (1884).

[76] *Proc. Roy. Soc.*, **84B**, 881 (1911).

[77] *Zeit. Farbenindustrie* (1913).

[78] *Zeit. Elektrochemie*, **17**, 1, 917 (1911).

[79] *Ibid.*, **11**, 8 (1912), **14**, 8 (1914).

When discussing the adsorption of gases by solids reference was made to cases of so-called contact catalysis. With solutions the effect of contact materials is as yet relatively unimportant. Lassar-Cohn[82] gives a few instances where yields have been increased by the use of porous masses. Gurwitsch[83] reports that amylene polymerizes readily on standing in contact with "floridin," which is a hydrous silicate of some sort. Richardson[84] believes that petroleum and bitumens are formed by the polymerizing or condensing action of clays or sands.

A case which has been studied a great deal quantitatively is the decomposition of hydrogen peroxide solutions by platinum. One of the most interesting things about this reaction is its sensitiveness to so-called poisons.[85] The rate of decomposition of hydrogen peroxide by a given solution of colloidal platinum is reduced approximately to one-half by M/20 000 000 HCN, M/2 000 000 $HgCl_2$, and M/300 000 H_2S. It has also been shown by Schönbein[86] that these same substances cut down the catalytic action of red blood-corpuscles on hydrogen peroxide. In Table VII are given data[87] for the concentrations necessary to cut down the rate of decomposition of hydrogen peroxide to one-half in the case of colloidal platinum and of hæmase, the active enzyme in the red blood-corpuscles. While many of the substances that cut down the platinum catalysis also decrease the catalytic action of hæmase, there are many cases where no parallelism occurs. Thus carbon monoxide is very toxic to platinum and has no effect on hæmase. On the other hand, nitric acid, sulphuric acid, potassium nitrate, and potassium chlorate have practically no effect on platinum and are quite toxic to hæmase. Even when there is a general parallelism, one must not follow it too closely. With platinum the prussic acid solution has one-tenth the concentration of the mercuric chloride solution, while with hæmase it has double the concentration. The tabulated

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[80] Bancroft, *Jour. Phys. Chem.*, **18**, 1, 118 (1914).

[81] Pelet-Jolivet, "Die Theorie des "Färbeprozesses," 95, 118, 149 (1910); Davison, *Jour. Phys. Chem.*, **17**, 737 (1913); Lake, *Ibid.*, **20**, 785 (1916).

[82] "Arbeitsmethoden für organisch-chemische Laboratorien," 584, 923, 1079 (1903).

[83] *Zeit. Kolloidchemie*, **11**, 18 (1912).

[84] *Jour. Ind. Eng. Chem.*, **8**, 4 (1916); *Met. Chem. Eng.*, **16**, 25 (1917).

[85] Bredig and von Berneck, *Zeit. phys. Chem.*, **31**, 258 (1899); Bredig and Ikeda, *Ibid.*, **37**, 1 (1901).

TABLE VII.

Concentrations at which Poisons reduce the Rate of the Catalytic Decomposition of Hydrogen Peroxide approximately to one-half.

Poison	Colloidal platinum	Hæmase
H_2S	M/300 000	M/1 000 000
HCN	M/20 000 000	M/1 000 000
$HgCl_2$	M/2 000 000	M/2 000 000
$HgBr_2$	....	M/300 000
$Hg(CN)_2$	M/200 000	M/300 000
I_2 in KI	M/5 000 000	M/50 000
$NH_2OH \cdot HCl$	M/25 000	M/80 000
Phenyl hydrazine	....	M/20 000
Aniline	M/5000	M/400
Arsenious acid	M/50	No poisoning at M/2000
CO	Very poisonous	No poisoning
HCl	M/3000	M/100 000
NH_4Cl	M/200	M/1000
HNO_3	No poisoning	M/250 000
H_2SO_4	No poisoning	M/50 000
KNO_3	No poisoning	M/40 000 at 0°
$KClo_3$	Slight poisoning?	M/40 000 at 0°

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[86] *Jour. prakt. Chem.*, **105**, 202 (1868).

[87] Senter, *Zeit. phys. Chem.*, **51**, 701 (1905).

concentration for mercuric chloride is the same as for hæmase, while that for iodine dissolved in KI is one hundred times as great for hæmase as for platinum. Kastle and Loevenhart[88] point out that prussic acid is a strong poison for colloidal platinum and silver, but accelerates the catalysis of hydrogen peroxide by iron and copper.

It is probable that the poisons are adsorbed strongly by the catalytic agent[89] and therefore prevent the adsorption of hydrogen peroxide. This adsorption will be specific and will therefore not be the same quantitatively for different catalytic agents. On the other hand, there may well be a qualitative agreement in some or even in many cases.

It would seem natural that a colloidal metal, with its enormous surface, would have a greater catalytic action than an equal weight of smooth foil, and this is usually true. Thus Jablczynski[90] found that platinized platinum decomposes chromous chloride three times as fast and hydrogen peroxide one hundred times as fast as does smooth platinum foil. On the other hand, Rosnyak[91] claims that the catalytic action of platinum on hydrogen peroxide decreases with increasing dispersity (fineness) of the platinum, and Felgate[92] states that pulverulent nickel reduces nitric oxide, while colloidal nickel does not. In both these cases it is probable that some factor has been overlooked or not stated. The more finely divided the platinum the more likely the surface is to be coated with oxide, and it does not follow at all that the catalytic action of metallic platinum is the same as that of an oxide of platinum. If the platinum is kept in suspension by means of gelatine or some similar substance, the adsorbed gelatine will probably decrease the adsorption of the reacting substances, and this may more than counterbalance the increased effectiveness due to increased surface. In the hydrogenation of oils, nickel in some form is apparently the catalytic agent most commonly used.

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[88] *Am. Chem. Jour.*, **29**, 397 (1903).

[89] Bancroft, *Jour. Phys. Chem.*, **21**, 734 (1917).

[90] *Zeit. phys. Chem.*, **64**, 751 (1908).

[91] *Ibid.*, **85**, 68 (1913).

[92] *Chem News*, **108**, 178 (1913).

ADSORPTION FROM SOLUTION BY LIQUID.

There is no reason why there should not be adsorption from a solution by a liquid just as well as by a solid, except that the matter is complicated by the possibility of the solute dissolving in the second liquid. An interesting case of such adsorption was studied by Wilson and others.[93] If a drop of chloroform or other organic liquid be placed under water in a dish and alkali be added, the drop flattens out, becoming rounder again when the solution is acidified. This change can be repeated apparently indefinitely. While the flattening of the organic liquid is clearly due to a change in surface tension, it cannot depend on the absolute surface tension of the water phase, because Wilson found the effect of alkali to be the same qualitatively whether sodium chloride was present or not, whereas the addition of salt increases the surface tension of the water phase. What happens is that hydroxyl is adsorbed at the dineric interface, lowering the surface tension and causing the organic liquid to flatten. This is confirmed by the experiments of von Lerch,[94] who determined the surface tension between benzene and aqueous solutions by means of the rise in capillary tubes. The adsorption of hydroxyl means practically a concentrating of alkali at the surface of the organic liquid, and consequently a closely adhering film of water. This accounts for Wilson's observation that the drops of chloroform are wetted readily by an alkaline solution. The presence of a surface film of caustic soda solution also accounts for the decreased mobility observed by Wilson.

Patrick[95] has studied the adsorption of new fuchsine, picric acid, salicylic acid, and mercurous sulphate from aqueous solutions by mercury. In all four cases the amounts adsorbed varied with the concentration, approximately, according to an exponential formula, and in all four cases the surface tension of the mercury was lowered by the adsorption.

ADSORPTION AND SURFACE TENSION.

When a substance dissolves in a liquid, the surface tension at the liquid-vapor surface changes, increasing in some cases and decreasing in others. Two solutions of the same density will not have the same surface tension. For this reason a hydrometer graduated for sulphuric acid solutions will not be accurate for hydrochloric acid solutions, because the amounts of solution which will rise up the stem will depend on the surface tensions and will therefore not be the same in the two cases. The surface tensions of solutions usually lie between the surface tensions of the constituents; but this is not necessarily true.[96] Röntgen and Schneider[97] found a maximum surface tension for sulphuric acid and water at about 48 per cent. H_2SO_4. Whatmough[98] obtained minima for a number of pairs of liquids. The change in surface tension with a solution is also accompanied by a change in concentration, the surface film of the solution having a different concentration from the mass of the liquid. The simple rule in regard to this is that the concentration in the film tends to change so as to decrease the surface tension.[99] Consequently the surface film will be more dilute than the mass of the solution if the dissolved substance increases the surface tension, and will be more concentrated than it if the solute lowers the surface tension of the solution. An equilibrium will be reached when the change in the surface tension is balanced by the difference of osmotic pressure between the surface film and the mass of the solution, always provided that we are dealing with a true solution. This can be expressed mathematically by the equation[100]

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[93] *Jour. Chem. Soc.*, **1**, 174 (1849); Swan, *Phil. Mag.* (3), **33**, 36 (1848); Twomey, *Jour. Phys. Chem.*, **19**, 360 (1915).

[94] *Drude's Ann.*, **9**, 434 (1902).

[95] *Zeit. phys. Chem.*, **8**, 545 (1914).

$$\Gamma = -\frac{d\alpha}{d\mu}$$

where α is the interfacial tension, μ is the chemical potential of the dissolved substance in the aqueous phrase, Γ is the mass of solute per unit area of interface (unspecified thickness) in excess of that corresponding to the concentration in the mass of the solution. In other words, Γ is the amount of solute adsorbed per unit area of interface in the interfacial transition layer of unspecified thickness. If the laws of dilute solutions apply, the preceding equations may be written

$$\Gamma = -\frac{C}{RT} \cdot \frac{d\alpha}{dc}.$$

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[96] See Freundlich, "Kapillarchemie." 58 (1909).

[97] *Wied. Ann.*, **29**, 165 (1886).

[98] *Zeit. phys. Chem.*, **39**, 129 (1902).

[99] J. Willard Gibbs, *Scientific Papers*. **1**, 219.

[100] Cf. Donnan and Barker, *Proc. Roy. Soc.*, **85A**, 557 (1911).

It is to be noted that these two equations apply only to a substance which is really in solution, a point which is apt to be overlooked in papers on colloids. On the other hand, there are many substances, such as soap, saponine, and gelatine, which are probably not soluble in water to any appreciable extent, but which form apparent or colloidal solutions with surface tensions lower than those of pure water. In these cases the concentration of the added substance will be higher in the surface film than in the mass of the liquid, but the Gibbs formula will not apply. As a matter of fact, the adsorptions, in the surface are 20 to 100 times those calculated from the formula with sodium glychocholate, Congo red, methyl orange, and sodium oleate.[101] Owing to the extreme and unknown thinness of the surface film, it has proved impossible so far to show the change of concentration with any true solution by means of direct analysis. An approximation has been obtained by measuring the surface tension through the drop number. The thickness of the transition layer probably varies in extreme cases from about 1 to 200 $\mu\mu$, being usually fairly near the smaller number.

If the difference in concentration between the mass of the solution and the surface layer is set up slowly, one ought to get one value for the surface tension when equilibrium is reached and another one if measurements are made rapidly on a fresh surface. This has been done experimentally by Lord Rayleigh,[102] though not for a true solution. His data have been recalculated by Freundlich,[103] who added some of his own. They are given in Table VIII. Except in the case of pure water, the surface tensions by the static method are higher than that of pure water in the case of the two very dilute sodium oleate solutions. Lord Rayleigh did not discuss this point, and Freundlich leaves it untouched. In the actual measurements an error of about 2 per cent. would account for the difference, which may be due to experimental error. There is another possibility: that the sodium oleate is completely hydrolyzed in the dilute solutions, and that what is measured by the dynamic method is really the surface tension of a caustic soda solution.

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[101] Willows and Hatschek, "Surface Tension and Surface Energy," 46 (1915).

[102] *Proc. Roy. Soc.*, **47**, 281 (1890).

[103] "Kapillarchemie," 56 (1909).

From the fact that the lowering of the surface tension is accompanied by an increase in the concentration of the surface film of a true solution, Freundlich [104] draws the conclusion that this is true in all cases, and that if a dissolved substance lowers the surface between the solid and the solution—whatever one may mean by that—the dissolved substance is adsorbed; conversely, that the dissolved substance is adsorbed only in case it lowers the surface tension at the interface. The conclusion may or may not be right, but the logic is faulty, because the two cases are not parallel. The Gibbs relation holds for a true solution, where the difference of concentration is entirely inside the solution phase. Freundlich is extending the relation to a heterogeneous system in which the adsorbed substance is presumably on the outer surface of the solid and by definition cannot diffuse into it, because we should then have a solid solution. It is very difficult to prove or disprove Freundlich's conclusion experimentally, but it is a great pity to have people believe, as many now do, that the generalization is based on sound thermodynamics.

TABLE VIII.

Static and Dynamic Surface Tensions of Solutions at Room Temperature.

Solution	Concentration, Per cent.	Surface tension in dynes/cm.	
		Static	Dynamic
Water..............	.....	75	75
Sodium oleate........	0.025	55	79
Sodium oleate........	0.25	26	79
Sodium oleate........	1.25	26	62
Sodium oleate........	2.5	26	58
Saponin..............	.....	52	73
Heptylic acid........	0.005N	54	68

BROWNIAN MOVEMENTS.

If a stone be dropped into water, it sinks rapidly; but if it be broken into small pieces, the surface is much greater and consequently the pieces sink more slowly. If the stone were ground into very fine particles, we should expect them to sink very slowly, the rate being a function of the diameter and the density of the particles. A formula has been deduced by

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[104] *Zeit. phys. Chem.*, **57**, 424 (1907).

Stokes,[105] which should hold after a constant rate of fall is reached. V is the constant rate of fall, r the radius of the

$$V = \frac{2.2^2(S-S')g}{9\eta}$$

particles, S their specific gravity, S' the specific gravity of the liquid, η its viscosity coefficient, and g the gravitational constant. Hatschek[106] has calculated the results for several special cases.[107] For particles of 1μ radius the rate of fall in water is calculated to be 2.4 mm. per minute. With gold particles of $10\mu\mu$ radius the calculated rate of settling in water is about 10 mm. per month. For a particle of $10\ \mu\mu$ radius and a specific gravity of only 3 the calculated rate is about 1 mm. per month. The formula does not hold experimentally when the particles are very fine. Eboll[108] states that ultramarine will stay suspended for months when obtained in a very finely divided state by grinding and elutriation. Mülhäuser[109] found that when very finely ground carborundum powder is treated with water a portion does not settle in months, and behaves in that respect like colloidal silver. Brewer[110] pointed out the slow rate at which clays settle, and raised the question whether extremely finely divided particles settle at all. If they do not, there must be some factor which neutralizes the action of gravity more or less completely. The experiments of an English botanist named Brown[111] furnish the clue to the difficulty, though the importance of these experiments was not appreciated until very much later. A microscopic study showed that extremely minute particles of any solid substance suspended in water exhibit irregular motions remarkably like those of bacteria. These movements of suspended particles are known as Brownian movements and are apparently due to the bombardment of the suspended particles by the molecules of the liquid.[112] From Exner's experiments[113] it appears that particles with a diameter larger than 4 μ show no perceptible Brownian movement in water. Particles smaller than 0.1 μ begin to show lively movements,[114] while particles with diameters of about 10 $\mu\mu$ give apparent trajectories up to 20 $\mu\mu$. In more viscous liquids the motion is, of course, less. The bombardment of the suspended particles will tend to give a uniform distribution. Under the influence of gravity we should get an increased concentration in the lower part of the vessel.[115]

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[105] "Mathematical and Physical Papers," **3**, 1 (1901).

[106] "An Introduction to the Physics and Chemistry of Colloids," 24 (1913).

[107] Elutriation, or the difference in the rate of settling, is much used in grading such powders as emery, carborundum, ultramarine, kaolin, etc.

[108] *Ber. deutsch. chem. Ges.*, **16**, 2429 (1883).

[109] *Zeit. anorg. Chem.*, **5**, 117 (1894).

[110] *Mem. Nat. Acad. Sci.*, **2**, 165 (1884); *Am. Jour. Sci.* (3), **29**, 1 (1885).

[111] *Phil. Mag.*, **4**, 161 (1828); **6**, 161 (1829).

[112] *Jour. de Phys.* (2), **7**, 561 (1888); *Comptes rendus*, **109**, 102 (1889).

[113] *Sitzungsber. Akad. Wiss. Wien.*, **56**, ii, 116 (1867).

"Let us suppose that it is possible to obtain an emulsion with the granules all identical, an emulsion which I will call, for shortness, *uniform*. It appeared to me at first intuitively that the granules of such an emulsion should distribute themselves as a function of the height in the same manner as the molecules of a gas under the influence of gravity. Just as the air is more dense at sea-level than on a mountain-top, so the granules of an emulsion, whatever may be their initial distribution, will attain a permanent state when the concentration will go on diminishing as a function of the height from the lower layers, and the law of rarefaction will be the same as for air.[116]" To test this hypothesis, Perrin prepared a uniform suspension of purified gamboge in water by means of fractional centrifuging. The results confirmed the hypothesis. With gamboge particles 0.3 μ in diameter a rise of 30 μ was sufficient to lower the concentration to a tenth of its value, 10 μ in the gamboge suspension being equivalent to six kilometers in the air. Similar results were obtained with mastic in water. Satisfactory results have also been obtained by Zangger [117] for drops of mercury, by Brillouin [118] for gamboge in glycerol solutions having a viscosity 160 times that of water, and by Iljin.[119] The mathematical theory has been developed by Einstein,[120] Smoluchowski,[121] and others. Perrin [122] considers that "the Brownian movement offers us, on a different scale, the faithful picture of the movements possessed, for example, by the molecules of oxygen dissolved in the water of a lake, which, encountering one another only rarely, change their direction and speed by virtue of their impacts with the molecules of the solvent. It may be interesting to observe that the largest of the granules, for which I have found the laws of perfect gases followed, are already visible in sunlight under a strong lens. They behave as the molecules of a perfect gas, of which the gram molecule would weigh 200,000 tons."

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[114] Zsigmondy, "Kolloidchemie," **18** (1912).

[115] Perrin, "Brownian Movement and Molecular Reality," 22 (1910).

[116] Perrin, "Brownian Movement and Molecular Reality," 43 (1910).

[117] *Zeit. Kolloidchemie*, **7**, 216 (1911).

[118] *Ann. Chim. Phys.* (8), **27**, 412 (1912).

[119] *Zeit. phys. Chem.*, **83**, 592 (1913).

[120] *Drude's Ann.*, **17**, 549 (1905), **19**, 289, 371 (1906).

[121] *Ibid.*, **21**, 756 (1906).

[122] Perrin, "Brownian Movement and Molecular Reality," 46 (1910).

It seems to be accepted pretty generally that the work of Perrin, Svedberg, and others has established the practical continuity between suspended particles and dissolved substances, but this seems to be an over-hasty conclusion. The molecular weight of a dissolved substance, as calculated from the osmotic pressure, means something quite definite. The molecular weight of a suspended particle, as calculated from any of Einstein's formulas, means something entirely different, if it means anything at all. We can determine the molecular weight of benzene approximately from the measurement of the surface tension, but it is absurd to say that suspending fine drops of benzene in water causes the molecular weight of benzene to become equal to 200,000 tons. We are talking about entirely different things in the two cases. What we mean is that liquid benzene has a molecular weight of 78, and that liquid benzene suspended in water behaves, or may behave, as if it were a dissolved substance having a molecular weight of 200,000 tons, more or less. As a matter of fact, the experiments bring out clearly the enormous difference between a solution and a supension.

The safe ground to take is: that the Brownian movements are due to the incessant bombardment by the molecules of the liquid; that the Brownian movements tend to make finely-divided, suspended particles distribute themselves throughout the liquid; that the uniform distribution is affected by the force of gravity, as in the case of a gas; and that the Brownian movements, though causing diffusion, give rise to no appreciable osmotic pressure. Very finely divided particles (less than 0.5 μ for instance) will be kept in suspension indefinitely by the Brownian movements, provided the particles remain finely divided. If enough particles agglomerate or coalesce, the force of gravity may cause the resulting masses to settle to the bottom of the containing vessel. We have therefore to consider some of the conditions under which particles coalesce or agglomerate.

COALESCENCE OF LIQUIDS.

If two small drops of a pure liquid are brought in contact, they run together and form a larger drop. The two small drops are therefore instable with respect to a larger drop. Consequently we should expect the small drops to distill over to, and condense on, a larger drop. This is equivalent to saying that the vapor pressure is higher the greater the curvature of the drop, a conclusion discussed by Lord Kelvin[123] many years ago. He considers that the theory, originally due to Laplace, is applicable to cases in which the radius of curvature is as small as 1.2 μ, but he thinks that we are not entitled to push it much further. Consequently he believes that the formulas given in his paper are not applicable to the vapor pressures of moistures retained by such substances as cotton cloth and oatmeal at temperatures far above the dew-point of the surrounding atmosphere, though the difference is quantitative and not qualitative. The rate at which small drops coalesce depends on the mobility of the liquid. With viscous liquids, such as cooling lavas or slags, one may get all sorts of phenomena which do not correspond to equilibrium relations.

COALESCENCE OF SOLIDS.

While it is perfectly familiar to everybody that two small drops of a pure liquid will coalesce readily to form a larger drop, all our ordinary experience is the other way in regard to solids, and yet, theoretically, finely divided solids behave like finely divided liquids in many respects. A very finely divided powder must have a higher vapor pressure, a lower melting-point, and a greater solubility[124] than the same substance in a more coarsely crystalline form. Crystals of iodine having a diameter of 2 to 3 mm. were kept in the dark for eight years. At the end of that time von Jonstorff[125] found that the smaller crystals had mostly disappeared, and that the crystals were now about 4.5 mm. in diameter. Pawlow[126] states that crystals of salol which were 2 μ in diameter melted 1.1° lower than crystals 40 μ in diameter. Comparing a fine dust of less than 2 μ diameter with crystals 0.5 to 2 mm. diameter, differences of 4° to 7° were obtained with salol, antipyrin, and phenacetin, but it seems probable that part of these differences is due to impurities and part also to experimental error.

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[123] *Phil. Mag.* (4), **42**, 448 (1871).

[124] Ostwald, *Zeit. phys. Chem.*, **35**, 495 (1900).

[125] *Ber. deutsch. chem. Ges.*, **10**, 866 (1877).

[126] *Zeit. phys. Chem.*, **65**, 1 (1908), **68**, 366 (1909).

Hulett[127] found practically no difference for the solubility of calcium sulphate in water until the diameter of the crystals was less than 4 μ. Changing from 4 μ to 0.6 μ caused an increase in solubility of nearly 20 per cent. A coarsely crystalline barium sulphate (3.6 μ) was soluble 2.3 mg. per liter. When ground in an agate mortar to 0.2 μ the solubility rose to 4.5 mg. per liter. The corresponding figures with natural barytes were 2.4 mg. and 6.2 mg. Red mercuric oxide has a solubility of 50 mg. per liter at 25°; when ground to a fine powder the color becomes yellow and the solubility increases to 150 mg. per liter.

The reason that the two parts of a broken plate do not coalesce when pressed together is that the film of condensed air acts as an elastic cushion and keeps the two parts from coming actually in contact.[128] If we heat the fragments of any broken object, less gas is adsorbed at the higher temperature and is held less firmly. If the solid becomes more malleable, it is easier to make contact at a number of points. It is possible to make two glass rods unite at temperatures at which the glass is still very viscous. It may be urged that glass at those temperatures is unquestionably a liquid and not a solid. This criticism does not apply to platinum, and it is easy to weld two pieces of platinum at temperatures far below that of the melting-point. In some cases two surfaces will unite fairly readily. This is very noticeable with unvulcanized rubber, from which it should follow that vulcanized rubber adsorbs air much more strongly. I do not know of any experiments along this line. While it is not possible, as a usual thing, to mend a broken object by pressing the two pieces together at ordinary temperatures, Spring[129] has shown that powders may be welded into massive blocks by the use of sufficiently high pressures. This means that the pressure has been sufficient to squeeze out the air films.

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[127] *Ibid.*, **37**, 385 (1901); Jones and Partington, *Jour. Chem. Soc.*, **106**, II, 612 (1915).

[128] See Breuer, "Kitte und Klebstoffe," 23 (1907).

[129] *Bull. Acad. roy. belg.* (2), **49**, 323 (1880); *Ann. Chim. Phys.* (5), **22**, 170 (1881); *Ber. deutsch. chem. Ges.*, **15**, 395 (1882); *Bull. Soc. chim. Paris* (2), **40**, 520 (1883); Friedel, *Ibid.* (2), **39**, 626 (1883); **40**, 526 (1883); Jannetz, Neel and Clermont, *Ibid.* (2), **40**, 51 (1883); Tammann, *Zeit. Elektrochemie*, **15**, 447 (1909).

Since solids will coalesce when heated and subjected to pressure, there is no reason why some solid powders should not coalesce to some extent under the influence of gravity when heated. This is known as sintering or sometimes as fritting. The two terms are not distinguished as sharply as they might be.[130] Sintering should be used when a powder coalesces without melting or with but slight fusion, so that the product is still granular and more or less porous. Fritting should be used when the fusion is quite marked and the product is distinctly glassy. The formation of bricks and pottery involves sintering while the materials for glazes are fritted. There has been some question whether sintering can take place without incipient fusion,[131] but it is clear that a pure crystalline substance may sinter.[132] The brown gold obtained in assaying sinters to yellow gold when heated,[133] and I am told that the sintering of tungsten powder is done technically. Soot becomes sandy if heated too long or too hot. Many precipitates sinter on standing, though the change is not usually called that.

Other things being equal, the sintering is greater, and consequently the density, the higher the temperature. Bricks are less porous the higher the temperature of burning. Of course, if the temperature of vitrification is reached, a new phenomenon occurs. Magnesia is more dense the higher it is heated,[134] and so is lime.[135] The agglomeration is often accompanied by increased resistance to chemical action. Strongly heated lime reacts very slowly with carbon dioxide.[136] After short ignition, silica dissolves in a boiling solution of potassium or sodium carbonate; after long ignition it does not.[137] The apparent action of caustic alkali on hydroxides and of gelatine and ammonia or potassium bromide on silver bromide is decreased enormously if the precipitates are allowed to stand over night.

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[130] Percy's Metallurgy: "Fuel," 46, 280 (1875).

[131] Lucas, *Zeit. phys. Chem.*, **52**, 327 (1905); Endell, *Silikat-Zeitschrift*, **2**, 1, 25 (1914); Kohlschütter, *Liebig's Ann.*, **398**, 37 (1913).

[132] Cf. Day and Allen, Carnegie Inst. Pub. **31**, 59 (1905); *Zeit. phys. Chem.*, **54**, 39 (1906).

[133] Percy's Metallurgy: "Silver and Gold," 268 (1880); Hanriot, *Comptes rendus*, **151**, 1355 (1910); **152**, 216 (1911).

[134] Ditte, *Comptes rendus*, **73**, 270 (1861); Moissan, *Ibid.*, **118**, 506 (1891).

[135] Wright, *Zeit. anorg. Chem.*, **68**, 397 (1910).

[136] Raoult, *Comptes rendus*, **92**, 189 (1881); Sosman, Hostetter and Merwin, *Jour. Wash. Acad. Sci.*, **5**, 563 (1915).

[137] Rammelsberg, *Jour. Chem. Soc.*, **26**, 242 (1873); cf. Laufer, *Ber. deutsch. chem. Ges.*, **11**, 60, 935 (1878).

PLASTICITY.

A plastic substance is one which can be moulded by pressure.[138] This connotes that any break due to deformation is self-healing. A mobile liquid is not plastic, because it will not retain its shape. With increasing viscosity a liquid becomes plastic. Molasses candy is plastic until it crystallizes. Semifused glass is plastic. The time factor may be important. Sealing-wax is brittle if the pressure is applied rapidly, but is plastic if the rate of deformation is low. Since metals and other solids coalesce under high pressure, there is no reason why they should not be plastic under similar conditions, as indeed they are. We make use of this property when squirting metals into rods or pipes. Under high pressure ice is plastic. It has been claimed by Spring[139] and by Kahlbaum[140] that solids become almost like mobile fluids under high pressure, but it seems to have been proved conclusively by Spezia[141] that this is not true when the pressure is uniform, and that the apparent fluidity occurs only when there is a shearing force. Iron filings in presence of a magnet might be considered a special case of plasticity, though not one of any great interest. Another special case of partial plasticity is the mineral itacolumite,[142] which is said to have a structure akin to a series of ball-and-socket joints.

Between the extreme cases of a solid such as a metal and a liquid such as glass or molasses candy we have the intermediate case of putty, which is whiting and oil, or a solid with a liquid film around it. If a liquid is adsorbed strongly by a solid, the thin film will hold the solid particles together, while still permitting them to move relatively to one another. A liquid film may therefore act as a bond for solids and may make the mass plastic. Oil is used as a binder in roads and to make plastic putty. Everybody knows that dry sand cannot be moulded.

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[138] Duff, "A Text-Book of Physics," 119 (1916).

[139] *Bull. Acad. roy. belg.* (2), **49**, 364 (1880).

[140] *Verh. Naturforscher ges. Basel*, **15**, 14 (1903).

[141] *Atti Acad. Sci. Torino*, **45**, 525 (1911); **46**, 682 (1912).

[142] Wetherill, *Chem. News*, **22**, 266 (1870).

whereas wet sand can. Plastic dynamite is made by adding three parts of nitroglycerin[143] to one part of diatomaceous earth. Bingham[144] has made a preliminary study of the concentration at which plasticity begins or ends. If a finely powdered solid is added to a liquid, the viscosity of the liquid is increased or the fluidity, which is the reciprocal of the viscosity, is decreased. Over the range from 25° to 60° the concentration for zero fluidity was independent of the temperature. With infusorial earth in water, zero fluidity was reached at a volume concentration of about 87 per cent. water; with China clay at about 96 per cent.; with the graphite used in Acheson's aquadag at about 94.5 per cent., and with an unspecified clay at about 80.5 per cent. With infusorial earth in alcohol, zero fluidity was reached at a volume concentration of about 88 per cent. alcohol. The mixtures having zero fluidity are not stiff and will not hold their shape. At higher concentrations of the solid there is a change from viscous flow to plastic flow. The distinction made by Bingham is that with viscous flow any shearing force—no matter how small—will produce permanent deformation, whereas, in the case of plastic flow, it is necessary to use a shearing force of finite magnitude in order to produce a permanent deformation. It seems reasonable to assume that zero fluidity corresponds to the point when liquid enough is present just to scatter the particles; in other words, when about enough liquid is added to fill the voids. This was true in the one case studied by Bingham. The clay referred to contained 81.6 per cent. voids and required 80.5 volume per cent. of water to bring it to zero fluidity. Of course, this very important generalization of Bingham's must be tested in more cases before it can be considered as definitely true, but it is so obvious, after it has been pointed out, that it cannot be far wrong. Bingham's law, if we may so call it, may be of distinct importance in the paint industry. The oil requirement for a given pigment is a very arbitrary amount, and experts often differ widely in their values. Reproducible figures could be obtained if in each case there was determined the amount of oil necessary to give zero fluidity.

The clay-workers use the word plasticity in a special sense to denote that a clay is plastic and will burn to a coherent mass. From this point of view a mass of wet sand is not plastic, because it falls to pieces when dried. To satisfy this new definition we must have in the water some bonding material, presumably in a gelatinous form. There is no difficulty in accounting for a gelatinous film.[145] Cushman[146] has shown that the cementing power of rock powders is due to the formation of gelatinous silica, ferric oxide, etc. If we have a gelatinous material which is adsorbed strongly by the solid particles and which can take up and lose water, we shall have plasticity. In the case of clay the gelatinous material may be hydrous alumina, hydrous silica, or some intermediate composition. The difficulty, however, is to account for its remaining plastic after moderate drying, to account for its re-adsorbing water to form a gelatinous mass. This is probably due to the presence of some salt, but we do not know what salt, and consequently we cannot tell why one clay is plastic and another not, and we do not know what we should add to a non-plastic clay to make it plastic. The whole thing is probably very simple, but no one has yet attacked it in a rational way.

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[143] Thorp, "Outlines of Industrial Chemistry," 482 (1916).

[144] *Am. Chem. Jour.*, **46**, 278 (1911); JOUR. FRANKLIN INST., **181**, 845 (1916).

Summary.

In this paper there has been given a discussion of: adsorption from solution by solid; the adsorption isotherm; abnormal adsorption; negative adsorption; reversibility of equilibrium; specificity of adsorption; adsorption of several solutes; adsorption from solution by liquid; adsorption and surface tension; Brownian movements; coalescence of liquids; coalescence of solids; plasticity.

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[145] Quincke, *Drude's Ann.*, 7, 74 (1902).

[146] *Jour. Am. Chem. Soc.*, 25, 451 (1903).

THE SPECTRAL SELECTIVITY OF PHOTOGRAPHIC DEPOSITS.*

Part I. Theory, Nomenclature, and Methods.

BY

L. A. JONES and R. B. WILSEY.

It is well known among practical photographers that the color of the silver deposit in a photographic negative exerts a marked influence upon the quality of the resulting print. Thus negatives made with certain developers exhibit decidedly yellowish deposits, while other developers produce images that are entirely colorless. Of two such negatives having the same visual quality except for the differences in color, the yellowish one will produce a print of decidedly greater contrast. The reason for this is immediately apparent upon consideration of the difference between the visibility function of the eye and the spectral sensibility (analogous to the visibility function) of the photographic printing material. The maximum of the visibility function lies at 554$\mu\mu$ in the green region of the spectrum, while the maximum of the photographic spectral sensibility is located in the violet between 380$\mu\mu$ and 440$\mu\mu$, the exact location varying between these limits for different sensitive materials. A deposit which is yellowish—that is, having excessive absorption for radiation of the shorter wave-lengths—therefore, will have a lower total transmission when measured by using some photographic material as a receiving surface for the transmitted radiation than when measured by a visual method in which the retina of the eye is employed as the light-sensitive receptor.

It is evident, then, in a study of negative quality, from the standpoint of tone reproduction, that a careful distinction must be made between the visual total transmission and the photographic total transmission of the silver deposits which compose the negative. Since the conception of photographic total transmission as distinguished from visual total transmission of such deposits is more or less new, it seems desirable, for the sake of clearness and uniformity in the terminology of future work to be done along this line, to define and name certain of the terms involved, and to outline experimental methods for their measurement.

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* Communicated by Dr. C. E. K. Mees. Communication No. 57 from the Research Laboratory of the Eastman Kodak Company.

In view of the fact that this paper is to deal with the relations existing between certain sensitometric constants as measured by two different methods, the visual and photographic, it may be well to review briefly the general methods in use at present in photographic sensitometry. These methods are based in general upon the work of Hurter and Driffield [1]; and to the papers published by them and the later photographic literature the reader is referred for detailed information regarding the theory, methods, and apparatus involved.

In order to obtain the characteristic curve of a photographic material (usually called the H. & D. curve) it is necessary to subject various areas of that material to series of known exposures varying over a wide range of magnitude. The exposed material is then developed, fixed, washed, and dried according to a set of standardized conditions, after which the extent of blackening produced by each of the different exposures is determined by some visual photometric method. The series of exposures, for the sake of convenience in plotting the results, usually vary according to some logarithmic function, such as by successive powers of 2 or of $\sqrt{2}$, and are given by a sensitometer embodying either some form of rotating sector wheel or some type of moving plate. The latter method is superior to the rotating wheel, as thus the errors due to intermittency, which are large under certain conditions, are entirely eliminated. The measurement of the total transmission of the various blackened areas may be made by any one of several types of photometer, the chief requirement being that the values obtained shall be the diffuse transmissions of the deposits measured. This result is usually obtained by placing the deposit, while being measured, in contact with a sheet of ground pot opal glass. The data thus obtained consist of a series of diffuse transmission values corresponding to a series of known exposures. Experience has shown that these data are most easily interpreted if plotted as a curve having log exposures as abscissæ and density values as ordinates, the density values being derived from the transmission values by the relation,

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[1] Hurter and Driffield, *Journal of Society of Chemical Industry*, 1890.

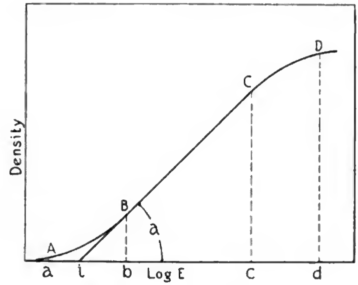
$$\text{Density } (D) = \log \frac{1}{\text{Transmission}} = \log \text{opacity},$$

$$D = \log \frac{1}{T} = \log O.$$

Such a curve is shown in Fig. 1.

It will be found that a portion of such a curve approximates closely to a straight line, the projection of which upon the x axis gives the "Latitude" value for that photographic material. The length of the straight line portion varies greatly with various types of photographic materials. In some cases the straight line may be entirely absent, being reduced to a point of inflection, while in the best negative materials the value of latitude (expressed in exposure units) may be as high as 250 or even 500.

FIG. 1.



The numerical values usually read from such curves (Fig. 1) and taken as representative of the characteristics of the material, are:

$$\text{Gamma } (\gamma) = \tan a$$
$$\text{Latitude } (L) = \log E_c - \log E_b$$
$$\text{Total Scale } (T) = \log E_d - \log E_a$$
$$\text{Speed } (S) = \frac{k}{i}$$

Where "a" is the angle between the straight line portion and the x axis, "k" is a constant depending upon exposure conditions, and "i" (inertia) is the value of E (exposure) where the straight line extended cuts the x axis. The positions of the points A and D (limits of the useful scale of the material) are established arbitrarily at the points on the curve where $\frac{dD}{d \log E} = 0.2$, it being considered that any portion of the curve having a gradient less than this value is practically useless in the reproduction of tone differences.

It is evident that, since the constants of a material determined in this way are dependent upon the total transmission values of the various silver deposits measured by some visual photometric method, such constants, when used for computing the effect of printing a negative upon a positive material, are correct in general only when applied to a positive sensitive surface having a spectral sensibility function identical with the visibility function of the retina. Since in all problems of tone reproduction we are interested in the effect of the negative on the positive material (which may be carried either upon an opaque base, such as paper, or upon a transparent medium, such as glass or film) and not in the visual appearance of the negative itself, and since such positive materials differ greatly from the retina in spectral sensibility, it follows that it is necessary to determine the total transmission values of the various deposits as referred to the sensitive positive material being used or to know the relation existing between such values and those measured visually.

The theoretical considerations involved in this problem are most clearly presented by the aid of a graphic representation of the various functions necessary for its solution (Fig. 2). Let us make the initial assumption that the same source of radiant energy is to be used in the determination of both the visual and photographic total transmission values. It should be borne in mind that this assumption applies to all discussion presented in this paper.

The various functions necessary for the complete mathematical solution of the problem are:

$J = f(\lambda)$ = Spectral energy distribution of the illuminant used for the measurement of both the visual and photographic values.

$T = f(\lambda)$ = Spectral transmission function of the deposit for which the visual and photographic total transmission values are desired.

$V = f(\lambda)$ = Visibility function of the retina.

$S = f(\lambda)$ = Spectral distribution of sensibility for the photographic surface.

$B = f(\lambda)$ = Spectral transmission function of the material (glass, film, etc.) upon which the silver deposit to be measured is supported.

The symbols J_λ, T_λ, V_λ, S_λ, and B_λ are used to designate the values of these various functions at some particular wave-length, λ. The ordinate values of the J function are in terms of relative energy; those of the T and B functions are the ratio of the transmitted to the incident radiation (pure numerics); while those of the V function are relative brightnesses of an equal energy source, plotted with maximum ordinate equal to unity. The ordinates of the sensibility function, S, represent relative sensitiveness, plotted with maximum ordinate equal to unity.

Although from a physical standpoint these spectrophotometric curves represent a complete specification of the characteristics of the various elements, they do not furnish the desired values in a directly usable form. For instance, in case of the spectral transmission function, T, of the silver deposit the thing of interest from the standpoint of tone reproduction is not its transmission at any particular wave-length, but the total transmission of that deposit as measured either by the retina or by the photographic material as a receiving surface. The functions shown in Fig. 2 do, however, provide the data from which the desired values may be computed.

For the determination of the visual total transmission, T_v, the following relations are found to exist:

$$\int_0^\infty J_\lambda V_\lambda \, d\lambda = E \cdot c$$

and

$$\int_0^\infty J_\lambda V_\lambda T_\lambda \, d\lambda = E' \cdot c$$

where

E = Total incident luminous flux.
E' = Total transmitted luminous flux.
c = constant of proportionality.

$$T_v = \frac{E'}{E} = \frac{\int_0^\infty J_\lambda V_\lambda T_\lambda \, d\lambda}{\int_0^\infty J_\lambda V_\lambda \, d\lambda}.$$

Similarly for the photographic total transmission, T_p,

$$\int_0^\infty J_\lambda S_\lambda B_\lambda \, d\lambda = A \cdot c'$$

$$\int_0^\infty J_\lambda S_\lambda B_\lambda T_\lambda \, d\lambda = A' \cdot c'$$

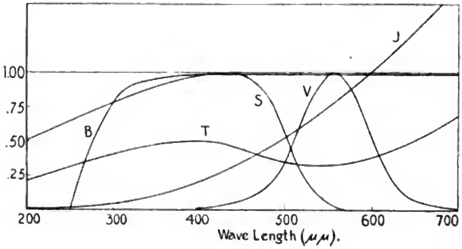
where

A = Total incident actinic flux.
A' = Total transmitted actinic flux.
c' = constant of proportionality.

$$T_p = \frac{A'}{A} = \frac{\int_0^\infty J_\lambda S_\lambda B_\lambda T_\lambda \, d\lambda}{\int_0^\infty J_\lambda S_\lambda B_\lambda \, d\lambda}$$

A complete and precise knowledge of the five functions shown in Fig. 2, therefore, would enable one to compute both the visual and photographic total transmission values for any given deposit. However, at present, certain of these functions are not known with sufficient precision, and their determination presents so many practical difficulties that it is more feasible to adopt some more direct method for the measurement of the values desired. The foregoing theoretical considerations have been presented not so much for their value in practical work but rather to assist in arriving at a clear understanding of the various factors upon which the values of visual and photographic transmission depend. Work is in progress at present on the improvement of apparatus and methods used in measurement of these uncertain factors, and it is hoped that sufficient precision will be secured to make the above method useful in checking the values of total transmission obtained by direct measurement.

FIG. 2.



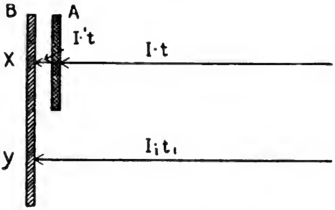
Now, turning to the direct methods of measuring these values, little need be said concerning the visual methods, since these are generally well understood. As previously stated, the value desired from the photographic standpoint, at least in all cases where a positive is to be made by contact printing from the negative, is that of "diffuse" density. The deposit to be measured, therefore, is illuminated by perfectly diffused light of the specified quality and E and E', the incident and transmitted intensities, are measured.

Then,

$$T_v = \frac{E'}{E}.$$

In making such measurements the retina is used as the sensitive receiving surface, and, since retinal response, at the intensities ordinarily used in such work, is proportional to the rate at which radiant energy impinges upon it, the measurement of visual transmission is independent of the time factor. The response of a photographic material, however, is not independent of time, being a function of both the intensity and the time of exposure. Over a considerable range of intensity values the response is proportional to the product of intensity by time $(I \cdot t)$, but this law breaks down for low values of intensity. This failure of the reciprocity law, as it is called, complicates to a certain extent the definition of the term photographic total transmission. In order to make the definition of this term, T_p, strictly analogous to that of visual transmission, T_v, and also to eliminate any effect of the failure of the reciprocity law, the following method is employed:

FIG. 3.



In Fig. 3, let A represent a photographic deposit the transmission of which is to be measured, and B the photographic sensitive surface for which the value of total transmission of A is desired. Let an exposure $I \cdot t$ be incident upon A. The area x of B which is covered by A thus will receive an exposure $I' t$, the value of which will depend upon the photographic total transmission of A.

Let an exposure $I_1 \cdot t_1$ be incident upon the area y of B, a portion of B not covered by A.

Now let the two areas x and y be developed to the same extent, *i.e.*, $\gamma_x = \gamma_y$, thus producing the densities D_x and D_y.

If $D_x = D_y$

and $t = t_1$

it is evident that $I' = I_1$.

$I \cdot t$ = Exposure incident upon A.
$I' \cdot t$ = Exposure transmitted by A.

Therefore,

$$T_p \text{ (for } A) = \frac{I' \cdot t}{I \cdot t} = \frac{I'}{I} = \frac{I_1}{I}.$$

And since

$$D = \log \frac{1}{T},$$

$$D_p \text{ (for } A) = \log \frac{1}{T_p} \text{ (for } A)$$

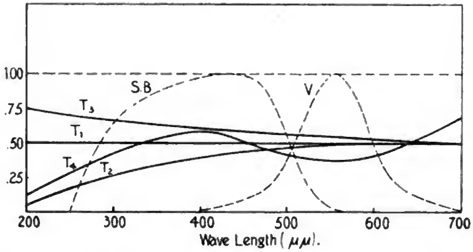
$$= \log \frac{I}{I_1}.$$

In this way a definition of photographic total transmission strictly analogous to the corresponding visual term is obtained, and any error due to the failure of the reciprocity law is eliminated. The measurement of the visual value is made by a null method, using the retina as the sensitive receiving surface, while by the definition outlined above the photographic value is also obtained by a null method, but by using the photographic material as the sensitive receptor. The requirement that $D_y = D_x$ in the discussion above makes the method a null one, while the assumption that $t = t_1$ is necessary for the elimination of errors due to reciprocity failure. It should be borne in mind that the value of photographic total transmission of any deposit depends upon the spectral sensibility of the material by which it is measured, and hence such values are correct only for materials having the same spectral distribution of sensibility. Photographic materials differ greatly in this respect, some being sensitive only to the extreme violet and ultra-violet while others respond to the entire visible spectrum as well. However, the great majority of positive materials available at present are quite similar in regard to spectral sensibility and measurements show that although differences do exist they are not of sufficient magnitude to cause serious errors in the results when using the value of photographic total transmission obtained by one material for work with others. These remarks apply only to the group of most extensively used developing-out papers and positive plates and films. A large amount of data has been obtained on this subject, and will be presented in the later parts of this paper, dealing with the more practical phases of the subject.

Now let us consider briefly the effect of the various forms of the transmission function upon the photographic and visual values of total transmission, and upon the relations existing between these values. In Fig. 4 are shown a few possible forms of this function.

The visibility, sensibility, and base transmission functions are shown as dotted curves, while the hypothetical T functions are shown as full lines and designated by number. No. 1—The value of T_λ is constant for all values of λ. Such a deposit is colorless (*i.e.*, neutral), and for such deposits $T_v = T_p$. No. 2.—The value of T_λ increases with increasing wave-length. Visually such deposits appear yellowish in color and $T_v > T_p$. This case represents practically all photographic images obtained by development with pyrogallic acid developers, the exact shape of the function depending upon the constitution of the developing solution, nature of fixing bath, etc. No. 3—The values of T_λ decrease with increasing wave-length. Such a deposit appears bluish in color and $T_v < T_p$. It is possible to obtain such deposits by use of indoxyl as the developing agent and also by some amidol formulæ.

FIG. 4.



From an inspection of the positions and shapes of the S and V functions, Fig. 4, it is apparent that it is possible to have deposits that may be entirely colorless (*i.e.*, non-selective throughout the visible spectrum) but with values of T_v either greater or less than those of T_p. The contrary may also be true; that is, a colored deposit for which $T_v = T_p$. An example of such a case is given by a silver deposit which has been intensified by a copper-tin method.[2] Visually this deposit has a magenta color and actual measurements gave $T_v = T_p$. A hypothetical curve representing this case is shown as No. 4, Fig. 4. By means of developing solutions so constituted as to control the state of division in which the silver is deposited it is possible to cause a great variation in the shape of the transmission function of the silver image and hence to alter the ratio of photographic to visual transmission. A wide variation in this factor also occurs in the case of many intensified deposits, especially in those cases where intensification is produced by the addition of materials other than silver to the original silver deposit.

Certain terms are frequently applied as descriptive of the transmission function of transmitting media, and in order to avoid confusion their meaning should be clearly defined. The term "selective" is used when the value of T_λ is variable with λ, while "non-selective" implies T_λ constant for all values of λ. These terms should not be used unaccompanied by a statement, either verbal or numerical, of the wave-length limits between which the implied condition exists. Thus "visually selective" and "visually non-selective" apply only to visible radiation the approximate limits of which are $400\mu\mu$ and $700\mu\mu$; while "photographically selective" and "photographically non-selective" apply to that range of wave-lengths to which the photographic material under consideration is sensitive. In case of the particular problem with which this paper deals, the production of a print from a series of silver deposits of varying density supported on a glass plate or film, the effective limits are approximately $500\mu\mu$ and $280\mu\mu$, the latter limit being determined by the base on which the deposit is supported (glass or film). The term colored as applied to a transmitting medium is analogous to "visually selective," while "neutral" has the same meaning as "visually non-selective." These terms may be summarized as follows:

$T_\lambda = K$ (between $400\mu\mu$ and $700\mu\mu$)—Visually non-selective or neutral.
$T_\lambda \neq K$ (between $400\mu\mu$ and $700\mu\mu$)—Visually selective or colored.
$T_\lambda = K$ (between $280\mu\mu$ and $500\mu\mu$)—Photographically non-selective.
$T_\lambda \neq K$ (between $280\mu\mu$ and $500\mu\mu$)—Photographically selective.

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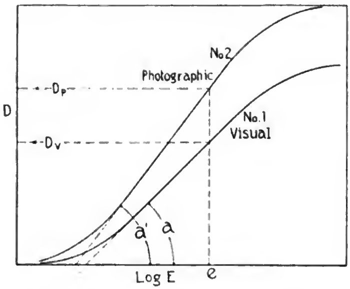
[2] Nietz and Huse, "The Sensitometry of Intensification." To appear in a future issue of this Journal.

Thus far the discussion has dealt only with the relative visual and photographic densities of a single silver deposit. Now let us turn to a consideration of the effect upon the characteristic curve of a photographic material resulting from the use of transmission (or density) values determined photographically rather than visually.

Considering a series of deposits, varying over a wide range of density, produced by any specified photographic method, we cannot in general assume that the ratio of T_p/T_v will be constant for the entire series. Hence both the shape and position of the curve may be changed by the use of the photographic values, and thus all of the sensitometric constants may be altered in value. Obviously, the constants obtained from the photographic values are the ones of greatest importance, for, since the negative is only an intermediate step in the process of reproduction, the visual appearance of the negative is of relatively little importance.

FIG. 5.



In Fig. 5 are shown the two curves illustrating a possible relation between the visual and photographic characteristics of a photographic plate.

Curve No. 1 is plotted from the visual density values and No. 2 from the photographic values of the same deposits. Now for any value of exposure, *e*, the corresponding values of D_v (viusal density) and D_p (photographic density) can be determined. Also both visual and photographic values of gamma, γ_v and γ_p, can be computed.

$$\tan a = \gamma_v = \text{Visual gamma.}$$
$$\tan a' = \gamma_p = \text{Photographic gamma.}$$

Likewise photographic values of all the various sensitometric constants, such as gradient, latitude, scale, inertia, etc., can be obtained.

The ratio between the visual and photographic values of certain of these constants is of considerable usefulness in expressing numerically the characteristics of negatives made by various processes, and hence it seems desirable to apply distinguishing terms to them.

For any value of exposure, *e*, Fig. 5:

$$\frac{D_p}{D_v} = \text{Selectivity coefficient of density} = \Delta \text{ (Delta)}$$

$$\frac{d\,D_v}{d \log E} = \text{Visual gradient} = G_v$$

$$\frac{d\,D_p}{d \log E} = \text{Photographic gradient} = G_p$$

$$\frac{\dfrac{d\,D_p}{d \log E}}{\dfrac{d\,D_v}{d \log E}} = \text{Selectivity coefficient of gradient} = \phi \text{ (Phi)}$$

These terms apply only to some single value of exposure, and such values are descriptive of only a single deposit or of a single point on the characteristic curve and are not of use in specifying the quality of a negative made up of a series of different densities. However, if the value of

$$\frac{\dfrac{d\,D_p}{d \log E}}{\dfrac{d\,D_v}{d \log E}}$$

is constant over the entire exposure range represented in a negative, this ratio may be taken as representing the selective character of that negative. Since the contrast of a negative is some function of the gradient, we may consider the value of the above ratio as an expression of the ratio of the photographic to the visual contrast. and hence for any negative for which this ratio is constant for all values of exposure this term may be called the "selectivity coefficient of contrast," κ (Kappa), of the negative.

Still another special case of the general problem is for the condition (in addition to the last limitation that the selectivity coefficient of gradient is constant) that the terms $\frac{d\,D_p}{d \log E}$ and $\frac{d\,D_v}{d \log E}$ are each constant for a considerable range of exposure. This condition exists over the straight-line portion of the curve, and the projection of this portion of the curve on the x axis gives the value of latitude for that sensitive material.

Under these conditions.

$$\frac{\gamma_p}{\gamma_v} = \frac{\dfrac{d\,D_p}{d \log E}}{\dfrac{d\,D_v}{d \log E}} = \text{color coefficient} = \chi\ (\text{Chi}).$$

In order to be strictly consistent in nomenclature, this term, $\frac{\gamma_p}{\gamma_v}$, should be called the selectivity coefficient of gamma, but since it must be used so frequently it is proposed to sacrifice precision of terminology for the sake of utility and to shorten the term to "color coefficient."

The word "color" used in this way is more or less misleading, for a negative showing no color (visually non-selective) may still be photographically selective and hence have a value of $\frac{\gamma_p}{\gamma_v}$ (color coefficient) other than unity, but for lack of a better term "color coefficient" has been adopted as being most convenient for use. The "color coefficient" is in practice the most useful constant for expressing the relation existing between its visual and photographic characteristics. For, as was previously pointed out, a straight-line portion ($\frac{d\,D}{d \operatorname{Log} E}$ = constant) is found in the characteristic curve of the majority of sensitive materials, and in a good negative material the length of this line is sufficiently great so that all ordinary subjects may be rendered on that portion of the curve. A good negative material should have a latitude of not less than 75, and, since but a very small percentage of subjects to be photographed have a contrast greater than 1 to 75, it is evident that by proper exposure the entire range of tones can be placed upon the straight-line portion of the curve and then, by developing to the proper extent, an exact reproduction of tone can be obtained in the negative. Under such conditions contrast is directly proportional to gamma, and the values "selectivity coefficient of contrast" and "color coefficient" become identical.

Having discussed the various relations existing between the visual and photographic characteristics of a negative, we come now to the consideration of the methods involved in the measurement of these relations in practice. The method used for the determination of the photographic transmission of a deposit must give values in conformity with the requirements of the definition of that term as outlined previously in this paper, involving the use of a null method free from errors due to the failure of the reciprocity law. Having determined D_p for each area of a sensitometric strip, a curve can be plotted with these D_p values against log E. In this way curve No. 2, Fig. 5, is obtained, and having this, together with the visual curve, No. 1, the various constants, such as color coefficient, etc., can be computed. The measurement of the photographic density of a series of deposits, in strict conformity with the definition of that term, may in some cases be unnecessary or even undesirable from the practical standpoint. However, as such values are sometimes desired, methods for obtaining such values will be outlined. Two such methods are presented, the first being as general and complete a solution of the problem as is possible in the light of our present knowledge of the subject, while the second is shorter and applicable only under certain conditions.

I. General Method for D_p.

This method involves the making of several prints from the sensitometric strip made up of the various densities to be measured, these prints being made with the strip in contact with the photographic material to which the values of D_p are to be applied. Successive prints differ in that the intensity factor, I_i, of the exposure incident upon the negative strip in printing is varied from print to print in some known manner, while the time factor, t_i, is kept constant for all prints. All of these prints are then developed to exactly the same extent, fixed, washed, dried, and the densities of the resulting deposits measured visually in the usual way. In case the positive material is coated on a transparent base the density values are read by transmitted light and $D = \log \frac{I}{T}$. If, however, the positive material is coated on an opaque support, such as paper, the density readings are obtained by reflected light, density being defined in this case by the equation $D = \log \frac{I}{R}$ where R is the reflecting power of the deposit as measured under specified conditions regarding the angle of illumination and observation.[3] From this set of prints a series of incident intensity values, all of which produce the same density in the prints, are obtained which are inversely proportional to the photographic total transmissions of the various deposits composing the negative strip. The procedure in obtaining the results can best be explained by a graphic presentation of the data as shown in Fig. 6.

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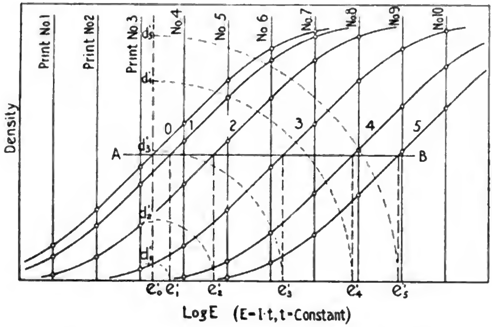
[3] Jones, Nutting and Mees, *Phot. Jour.*, December, 1914, p. 342.

Assume that the negative strip consists of six areas, 0, 1, 2, 3, 4 and 5, the visual density values of which are d_0, d_1, d_2, d_3, d_4, and d_5, and the photographic density values d_0, d'_1, d'_2, d'_3, d'_4, and d'_5. The series of prints are made from this strip on the positive material for which it is desired to determine the values of d'_1, d'_2, etc. Let E_i be used as a general symbol for the exposure incident upon the negative, and E_t for the exposure transmitted by the negative.

FIG. 6.



$$E_i = I_i \cdot t_i \text{ and } E_t = I_t \cdot t_t.$$

E_t, the transmitted exposure, is equal to the exposure incident upon the positive material at that point, $E'_i = (I'_i \cdot t'_i)$. E_i is increased in some known manner from print to print, usually by equal logarithmic increments, the magnitude of the increment from print to print being determined by the densities to be measured and by the character of the positive material being used.

Thus:

E_i for first print $= e = I_1 \,.\, t_1$.
E_i for second print $= 2e = 2I_1 \,.\, t_1$.
E_i for third print $= 4e = 4I_1 \,.\, t_1$.
E_i for fourth print $= 8e = 8I_1 \,.\, t_1$, etc.

The change in E_i must be accomplished by a variation of I_i, keeping t_i constant. Further, E_i should be varied over such a range that for its lowest value a low density is obtained on the positive material for the area of the negative where $D = 0$, while for the highest value of E_i a high density is obtained under the negative area having the highest density (d_5 in this case). The prints having been developed as previously specified and the density values of the resulting deposits having been determined, the values are plotted as shown in Fig. 6. The densities from any particular print are all plotted as ordinates at the same log E value, where E is the value of the exposure incident on the negative during printing. Densities from the first print were plotted where log E = log e, those from the second print where log E = log $2e$, etc. Then by connecting all of the points plotted from the densities printed under the area No. 0 of the negative (for which $D = 0$) the curve No. 0 is obtained, and in a similar manner a curve is obtained for each of the deposits on the negative strip, curve No. 1 for deposit No. 1, etc. All of the curves thus obtained will be exactly similar in shape but separated by intervals from which the photographic densities of the various deposits can be computed.

The statement that the family of curves shown in Fig. 6 are similar in shape (all curves having the same gradient at any particular value of D) depends on an assumption that should be mentioned at this point. Since the silver deposits being measured may be selective in transmission, it follows that the quality of the transmitted radiation may be different for the deposits of different density and also different from the quality of the incident radiation, which obviously is identical in quality with the radiation transmitted by the area of zero density; *i.e.*, directly incident upon the positive material. It is known that with some positive materials, at least, the gradient obtained with fixed conditions of development may vary with the wave length of the radiation used in making the exposure. It follows, therefore, if all the prints referred to above are developed for equal times, that the change in the quality of radiation due to the selectivity of the negative deposits may result in different gradient values for the curves in Fig. 6. If such is the case, each negative density must be taken separately and a series of prints made from each, with I_t variable and t_t constant. The series of prints from each density are then developed together, the development time from series to series being so changed that the curves when plotted will all have the same gradient. In this way a set of curves similar to those shown in Fig. 6 will be obtained. In case it is found necessary to use various times of development in order to obtain curves having equal gradient, a developing solution must be used which produces no change of inertia with time of development; that is, one containing no bromide or only a very small amount. If the positive material being used contains free bromide, a change in the inertia will occur with a variation in development time, but this may be considered as a characteristic of the positive material and hence may rightfully be allowed to influence the density value of any given deposit as measured by that particular positive material. In practice it is found that the great majority of selective deposits obtained by ordinary processes of development change the quality of the transmitted radiation to so slight an extent that the variation in gradient obtained with fixed times of development is negligible and therefore the method outlined in Fig. 6 is applicable. However, the assumption that a fixed time of development will give curves of equal gradient should be borne in mind and its validity tested in any doubtful cases. It is evident that the methods outlined in this paper may be used in the determination of the photographic transmission of any transmitting medium, such as gelatine filters, colored glass, etc., as well as for silver deposits, such as make up negative images. In the case of highly colored media the variation of gradient with the quality of transmitted radiation may be quite appreciable, and in such cases the above assumption does not hold, and means must be adopted for obtaining curves of equal gradient without changing the inertia except in so far as the inertia is a function of gradient due to inherent characteristics of the positive material being used.

Returning now to a consideration of the curves as shown in Fig. 6. it is evident, upon examination, that curve No. 0 (for the negative deposit where $D = 0$) may be regarded as a true characteristic curve of the positive material obtained by giving a series of exposures in which t_t is kept constant and I_t varied. By definition photographic transmission, T_p, is given by the ratio,

$$\frac{E_t}{E_i} = \frac{I_t \cdot t_t}{I_i \cdot t_i} = \frac{I_t}{I_i} = T_p,$$

where E_i = incident exposure,

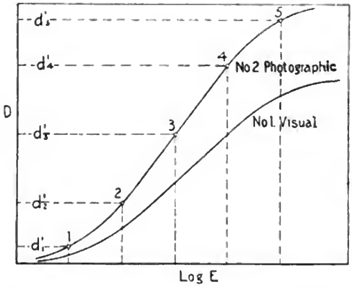
E_t = transmitted exposure,

and $t_i = t_t.$

Therefore
$$D_p = \log \frac{E_i}{E_t}$$
$$= \log E_i - \log E_t.$$

Now, if a line, AB, of constant density (any horizontal line) be drawn intersecting the curves 0, 1, 2, etc., and the log E values of the points of intersection be read from the log E scale, D_p can be computed for the various negative deposits, 1, 2, 3, etc. Considering deposit No. 1, for instance, it is evident that an incident exposure e'_1, produces a density on the positive material equal to that produced by the exposure e'_0 incident through zero density, t_1 being equal to t_0. e'_0, therefore, must be equal to the exposure transmitted by the deposit No. 1. Hence,

FIG. 7.



$$D_p \text{ (for deposit No. 1)} = \log e'_1 - \log e'_0$$

and

$$D_p \text{ (for deposit No. 2)} = \log e'_2 - \log, e'_0, \text{ etc.}$$

The difference between log e'_0 and the log e' value for any other deposit, then, is equal to D_p for that deposit. Now in Fig 7 plot these values, making $d'_1 = \log e'_1 - \log e'_0$, $d'_2 = \log e'_2 - \log e'_0$ etc., against the log exposures given to the negative. These points, 1, 2, 3, 4, etc., give curve No. 2, which is the photographic characteristic of the negative referred to the positive material used, curve No. 1 being the visual curve of the same negative. It is evident that the d'_1, d'_2, etc., points can be established by a graphic method if desired by simply rotating the e'_1, e'_2, etc., points about e'_0 (Fig. 6) until they lie upon a perpendicular through e'_0, this perpendicular being the density scale with e'_0 at the point $D = 0$.

II. Shorter Method for D_p.

Referring again to Fig. 6, since all of the curves are of the same shape, it follows that the line AB may be drawn at any value of D without changing the value of $\log e'_1 - \log e'_0$ or D_p for deposit No. 1. It follows, furthermore, that the line the length of which determines the value of D_{p_1} need not be drawn at the same value of D as that which determined the value of D_{p_2} or of any other of the various deposits. Therefore if curve No. 0 be completely determined it is evident that only one point on each of the other curves is necessary for the solution of the problem. A single print from the negative strip (if E_i be of the proper magnitude) gives one point on each of the curves, 0, 1, 2, 3, etc., and hence with curve No. 0 provides all of the data needed. Curve No. 0 can be obtained by exposing the positive material in a sensitometer which gives a series of exposures in which the time, t_i, is constant and the intensity, I_i, is varied over the required range and in steps of known magnitude. In case the negative strip has a contrast greater than the total scale of the positive material it will be necessary to make a second print with incident exposure, $N \cdot E_i$ [where $N \cdot E_i = (N \cdot I_i) \cdot t_i$], in order to obtain D_p values for all of the deposits composing the negative strip.

The contact print or prints and the strip exposed in the sensitometer are then developed for equal times, fixed, washed, and dried under exactly similar conditions throughout, after which the resulting densities are read in the usual way.

The method of plotting the data in order to obtain the desired values of D_p is shown in Fig. 8. Curve No. 0 is the same as No. 0 in Fig. 6, being the characteristic curve of the positive material made with I variable and t constant. The densities d'_1,

d'_2, d'_3, etc., read from the contact print, for which the incident exposure on the negative during printing is E_i, are all plotted as ordinates where $\log E = \log E_i = \log I_i \cdot t_i$. The densities read from the second contact print, in case it is found necessary to make a second in order to include all of the densities of the negative strip, are plotted as ordinates where $\log E = \log N \cdot E_i$.

Now

$$D_p = \log Ei - \log Et,$$

where

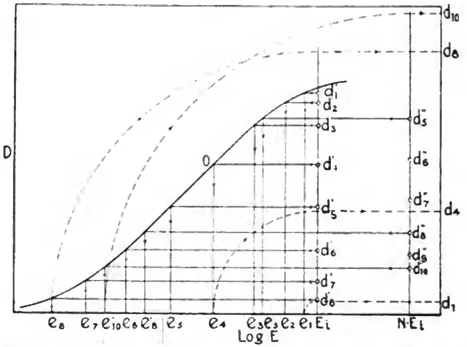
$$Ei = \text{incident exposure},$$

and

$$Et = \text{transmitted exposure}.$$

The incident exposure (on the negative) in case of the first contact print is E_i, while the transmitted exposure for the various negative deposits, 1, 2, 3, etc., are e_1, e_2, e_3, etc., the values of which are obtained as indicated by the light lines, Fig. 8, the value of e_1 being obtained by reading the log E value of the point of intersection of the curve No. 0 with a horizontal line through d'_1, and similarly for other values.

Fig. 8.



Therefore

$$D_p \text{ (for deposit No. 1)} = \log Ei - \log e_1 = d_1,$$
$$D_p \text{ (for deposit No. 8)} = \log Ei - \log e_8 = d_8,$$
$$D_p \text{ (for deposit No. 8)} = \log N.Ei - \log e'_8 = d_8,$$
$$D_p \text{ (for deposit No. 10)} = \log N.Ei - \log e'_{10} = d_{10}, \text{ etc.}$$

The values of D_p thus obtained may now be plotted against the log E values for the various negative deposits and the photographic characteristic curve of the negative thus obtained.

The various values of D_p may be obtained graphically by transforming the log E scale upon which the value of e_1, e_2, e_3, etc., are situated into a density scale. This may be accomplished by rotation of the points e_1, e_2, to e_8 about the point E_i as a centre until they lie on the perpendicular through E_i, the points e'_9 to $e^1{}_{10}$ being rotated about $N \cdot E_i$ as a centre till they lie on the perpendicular through $N \cdot E_i$. Now by projecting the points thus established horizontally onto the density scale the values d_1, d_2, d_3, etc., to d_{10} are obtained. This graphic solution is illustrated in Fig. 8 for the deposits 1, 4, 8, and 10.

This method for obtaining values of D_p involves the assumption that the variation of gradient with quality of radiation transmitted by the deposits being measured is so small as to be negligible. Moreover, the method does not afford means of deciding whether this assumption is or is not valid for any particular case. Therefore this method should be used only when this assumption is known to be in agreement with the facts or after verification by the first method, which shows at once any variation of gradient due to the change in quality of the transmitted radiation.

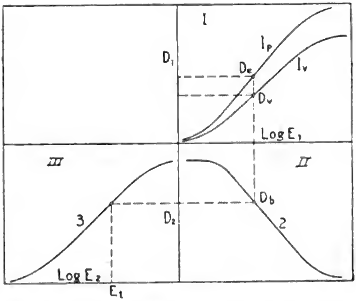
Now it will be noted that the procedure outlined in the methods just presented is not strictly analogous to that ordinarily followed in obtaining a print from a negative. The quality of a print made under usual conditions must necessarily be influenced by any variation of gamma with wave-length that may exist, for it is obviously impossible to change the time of development for various areas of the print in order to compensate for such variations of gamma. Of even greater importance is the effect of the failure of the reciprocity law upon the quality of a print made in the usual way. In the preceding methods care has been taken to obtain values of D_p which are not dependent upon the absolute values of the I or t factors of exposure, thus eliminating, in so far as is possible, any effect of the failure of the reciprocity law upon such values. Now it is evident that if, for the positive material being considered, a failure of this law exists within the range of intensities transmitted by the various areas of the negative during printing, such failure will have an influence upon the quality of the resulting print. Any method of computing the tone reproduction obtained by means of such a negative must therefore take account of this failure of the reciprocity law. Since the curves of photographic density obtained by the previous methods are plotted from values from which any effect of reciprocity failure has been specifically eliminated, it follows that if such a curve is to be used in computing tone reproduction the reciprocity failure under the specified conditions of printing must be introduced at some other point in the process. In practice, however, it is found more convenient to obtain for this purpose a photographic characteristic curve for the negative strip in which is included any reciprocity failure that may occur under the conditions that exist in making a print from the negative, such conditions being specified by the absolute value of the I and t factors of the exposure given in printing. With the majority of positive materials when used with negatives of ordinary quality and with the intensity of printing light usually employed in printing, any effect due to the failure of the reciprocity law is negligible, or at least very small. However, it is possible, by using a printing light of very low intensity and a correspondingly long exposure, to observe this effect, a print made in such a way being more contrasty than one made from the same negative by exposing for a shorter time to a source of higher intensity.

It is evident, from these considerations, that the photographic curve desired, from the standpoint of the reproduction problem, is one that will represent the photographic printing quality of the negative or sensitometer strip under the conditions of actual use. Such a curve must include any effect due to failure of the reciprocity law, and also any effect due to variation in quality of radiation transmitted by the negative, in order to represent the quality of the negative from the practical standpoint. In case these effects do not exist with the materials and under the conditions of printing, the photographic characteristic curve obtained by such a direct printing method will be identical in shape with that obtained by plotting the D_p values of the various deposits as determined in strict conformity with the definition of that term. Such curves, then, represent the actual characteristics of the negative deposits when used under certain specified conditions and enable us to compute the relation between the scale of tone values existing in the original and that reproduced in the positive material by printing from this series of negative deposits under those specified conditions. These curves represent what may be termed the "effective printing characteristics" of the negative strip, and the density values read from such curves, since they may or may not represent actual photographic density, should be referred to as "effective printing densities."

Methods for Effective Printing Density.

In general three groups of data from which three curves may be plotted are required for a solution of this problem. They are as follows: (*a*) The visual density values for the various areas of the sensitometer strip and the corresponding exposure values; (*b*) the density values from a contact print made from the negative strip on the positive material for which the effective printing density values of the negative deposits are desired; (*c*) the density values from a strip of the positive material exposed in the sensitometer and developed along with the contact prints, and the values of the exposures given by the sensitometer to the various areas of this strip. Three methods of reducing these data will be presented, differing slightly in detail. The method most applicable to any particular case will depend upon circumstances and upon the results desired.

FIG. 9.



The first method will be explained by use of Fig. 9. In the first quadrant are plotted (curve No. 1_v) the visual values of density obtained from the negative strip for which the effective printing densities are desired, the ordinates being density and the abscissæ log E values. A print from this negative strip is made on the desired positive material, and the visual densities of the resulting deposits are measured. In the second quadrant these values are plotted (curve No. 2) against the log E_1 values applying to the corresponding areas of the negative from which the print was made. Let the exposure incident upon the negative strip during printing be designated by E_i. The magnitude of E_i should be such that a just perceptible deposit is obtained on that portion of the positive material printed under the highest density of the negative strip. This is true only if the positive material has sufficient scale for the reproduction of the entire range of contrast existing in the negative. In case the scale is insufficient it will be impossible to obtain a complete printing characteristic from a single print, and two or more prints covering different portions of the negative must be made. In the third quadrant is plotted (curve No. 3) the characteristic curve of the same positive material on which the print from the negative strip was made. This is obtained by exposing the material in a sensitometer to light of the same quality as was used in making the print. The values of the exposure incident upon the various areas are therefore precisely known, and the densities of the resulting deposits are determined visually. The material on which the print is made and that exposed in the sensitometer must receive exactly the same treatment in development, fixing, etc. The highest precision is obtained by making the sensitometric exposures and the contact prints side by side on the same sheet of positive material, thus assuring identical treatment in development and also eliminating any variation in character that may occur from sheet to sheet of the most carefully prepared sensitive materials.

Now the curve in the second quadrant is a true reproduction curve and represents the way in which any scale of tones laid off on the log E_1 axis will be reproduced by use of these negative and positive materials when subjected to exposure and development identical with those used in obtaining this curve. However, since this paper does not deal with the question of tone reproduction, the curve will be regarded from an entirely different standpoint. It may be regarded as the resultant of two curves, the photographic characteristic of the negative and the visual characteristic of the positive material. Since of these two the latter is known, the former may be obtained.

The first problem to be considered is that of finding for any visual density of the negative the corresponding effective printing density. Take any value, D_v, on Curve No. 1, from this print drop a perpendicular to the log E_1 axis cutting curve No. 2 at D_v. The value of D_b, read from the D_2 scale, is the visual density produced on the positive material printed under the visual density D_v of the negative by an exposure E_i incident upon the negative. Now since curves Nos. 2 and 3 were obtained under exactly similar conditions of development, fixing, etc., it is evident that the exposure necessary to produce a density of D_b in one case must be effectively equal to that required to produce the same density in the other case. This exposure, E_t, is obtained by reading the value on the log E_2 scale at the point corresponding to a density of D_b, and is the exposure transmitted by the negative area having a usual density of D_v.

It is evident, then, for the visual density, D_v, that

$$E_i = \text{incident exposure,}$$

and

$$E_t = \text{effective transmitted exposure.}$$

Therefore

$$\frac{E_t}{E_i} = \text{effective printing transmission} = T_e,$$

and

$$\log \frac{E_i}{E_t} = \text{effective printing density} = D_e,$$

or

$$\log E_i - \log E_t = \text{effective printing density} = D_e.$$

Now this value D_e is plotted in the first quadrant at the log E_1 value corresponding to D_v, and in similar manner values for other points on curve No. 1_v are obtained which, when connected, give curve No. 1_p, the curve of effective printing density.

Obtaining curves in this way involves considerable computation, although a set of values may be carried through much more rapidly than the explanation of the method would indicate. Since in some cases the position of the curve 1_p is of no particular importance, its shape only being of interest, it is possible to shorten the method somewhat and still obtain all the information necessary. This is true when values of the selectivity coefficient of gradient or of color coefficient are desired, and the values of effective printing density are not important. These latter values are needed only when it is desired to compute the exposure required to produce a correctly exposed print from a given negative.

Before proceeding further with the discussion, it may be well to demonstrate the method of converting a scale of density values into a corresponding scale of exposure values, for the positive material exposed under the negative deposits. Let E_i be the exposure incident upon the negative during printing and T the transmission of the deposit being considered. The exposure transmitted, E_t, by this deposit and therefore incident upon the positive material in contact with that portion of the negative, will be given by,

$$E_t = E_i \cdot T.$$

Now E_i is constant for all portions of the negative, while T is variable, and hence E_t varies directly as T.

$$\begin{aligned} \log E_t &= \log E_i + \log T \\ &= \log E_i - \log O \\ &= \log E_i - D. \end{aligned}$$

Since E_i is constant, differentiation of the above gives

$$d \log E_t = -dD.$$

Hence any interval on the log E scale is numerically equal to the corresponding interval on the density scale, but of opposite sign. In this way any scale of densities may be converted into a log E scale, or *vice versa*. Of course, if the values of density used are visual, the log E values will also be visual, and similarly for the photographic density values.

Thus

$$d \log E_t \text{ (photographic)} = -dD_p,$$

and

$$d \log E_t \text{ (visual)} = -dD_v.$$

It will be noted that the negative is being regarded simply as a means of impressing a certain series of various exposures on the positive material, and that the visual exposure transmitted by any given area of the negative may be equal to, greater, or less than the photographic exposure transmitted by that area.

Referring now to Fig. 10, the four curves are plotted again as in Fig. 9.

No. 1_v—Characteristic curve of negative (visual).

No. 1_p—Characteristic curve of negative (effective photographic).

No. 2—Reproduction curve (contact print from negative).
No. 3—Characteristic curve of positive material.

The visual gradient of No. 1_v at any value, *a*, of log E_1, is

$$G_{1,v} = \frac{dD_v}{d \log E_1},$$

the photographic gradient at the same value of log E_1 being

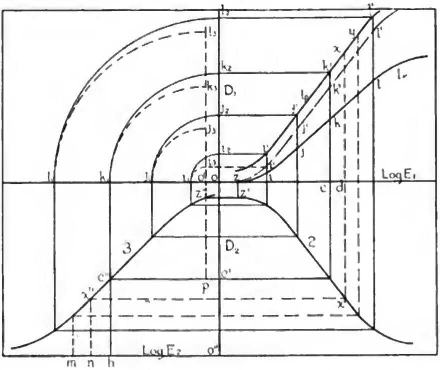
$$G_{1,p} = \frac{dD_p}{d \log E_1},$$

For the same value of log E_1 the gradient of the reproduction curve is,

$$G_2 = \frac{-dD_2}{d \log E_1},$$

and at the point on curve No. 3 where the density is equal to the density of the reproduction curve (No. 2) at the point to which the above expression applies, the gradient is,

FIG. 10.



$$G_3 = \frac{dD_3}{d \log E_2}.$$

Now, the ratio of the effective exposures (effective E_p) transmitted by any two deposits of the negative strip, the effective printing densities of these deposits being represented by the points *x* and *y* on curve 1_p, will be given by the ratio of *m* to *n*. The points *m* and *n* are located on the E_2 axis, as indicated by the dotted lines connecting x with n and y with m. Since it has been shown that any $d \log E$ value may be converted into a dD value by the expression,

$$d \log E = -dD,$$

it follows that we may write,

$$d \log E_2 = -dD_{1,p}$$

where $D_{1,p}$ = effective printing density.

and E_2 = effective exposure.

Therefore,

$$G_3 = \frac{-dD_2}{dD_{1,p}},$$

and

$$\frac{dD_{1,p}}{d \log E_1} \times \frac{-dD_2}{dD_{1,p}} = \frac{-dD_2}{d \log E_1}$$

or

$$G_{1,p} \times G_3 = G_2.$$

Stating this in words, we have, that the product of the photographic gradient of the negative, by the gradient of the positive material is equal to the gradient of the reproduction curve. This applies only, of course, to gradient values determined at corresponding points on the three curves, corresponding points being defined as any three points related to each other as x, x', and x''. Fig. 10.

It is evident now that, since curves Nos. 2 and 3 can be determined experimentally, G_2 and G_3 can be obtained, and from these values $G_{1,p}$ may be computed for any point, and since $G_{1,v}$ is also known (from curve No. $1v$), the ratio $\frac{G_{1,p}}{G_{1,v}}$, the selectivity coefficient of gradient, may be obtained.

A graphic method of obtaining the complete effective printing curve of the negative strip is also illustrated in Fig. 10. Consider a series of points, i, j, k, and l on the negative curve (visual) No. $1v$. Project these points onto curve No. 2, as indicated by the light full lines, thence onto curve No. 3, and finally onto the $\log E_2$ axis at the points i_1, j_1, k_1, l_1. Now this series of intervals on the $\log E_2$ scale may be transformed into a series of intervals on the D_1 scale according to the relation,

$$d \log E = -dD.$$

This may be accomplished graphically by rotating each point (i_1, j_1, k_1, and l_1) about the origin O as a centre until they lie on the D_1 scale at the points i_2, j_2, k_2, l_2, and through these points draw horizontal lines intersecting vertical lines through the points *i*, *j*, *k*, and *l* on curve No. 1. These intersections determine the positions of the points *i′*, *j′*, *k′*, and *l′*, which, when connected, give the curve 1_p the effective printing characteristic for the negative strip. This curve is of the correct shape, and from it and No. 1 values of the selectivity coefficient of gradient and of color coefficient may be obtained. The actual values of effective printing density read from this curve, however, will be correct only when certain conditions in regard to the position of curve No. 3 are fulfilled. Considering any point, *k*, on curve No. 1_p the effective transmitted exposure E_t is given by the value of log E_2 at the point *h*, this point being located as indicated in the diagram. The effective transmission T_p of the deposit represented by the point *k* is, therefore, given by the expression

$$T_p \text{ (for k)} = \frac{E_t}{E_i},$$

$$D_p \text{ (for k)} = \log \frac{E_i}{E_t} = \log E_i - \log E_t;$$

$$\text{also } D_p \text{ (for k)} = \text{the line } c\,k' \text{ (Fig. 10),}$$

$$\text{and } c\,k' = Ok_2 = Ok_1 = c'\,c'' \text{ (Fig. 10).}$$

$$c'\,c'' = \log E_i - \log E_t.$$

Therefore, if the scale of log E_2 be so constructed with reference to the point *O* or *O″* that when curve No. 3 is plotted the condition that $c'\,c'' = \log E_i - \log E_t$ is satisfied, the derived curve No. 1_p will be correct both in shape and position, and values read from the D_1 scale will be correct values of effective printing density for the deposit considered.

In practice it may be found inconvenient to establish the log E_2 scale as indicated above, and in such cases the same result may be obtained in a slightly different way. Curve No. 3 having been plotted on the log E_2 scale in any arbitrary relation to the point *O″*, establish the point *p* on the line *c″ c′* such that $c''p = \log E_i - \log E_t$. Through *p* draw a line *p o′* perpendicular to and intersecting the *x* axis at *O′*. The points i_1, j_1, k_1, and l_1 must now be rotated about *O′* as a centre until they fall upon the line *pO′* extended, thus establishing the points i_3, j_3, k_3, and l_3. Horizontals through i_3, j_3, k_3, and l_3 intersecting the perpendiculars through *i*, *j*, *k*, and *l* now establish the correct position for the points *i′*, *j′*, *k′*, and and *l′*. Curve No. 1_p (dotted line) is established in this way. No. 1_p (solid) is correct in shape, but is displaced by a shift in the vertical direction from the correct position, this displacement being due to the fact that $c'c''$ is not equal to $\log E_i - \log E_t$. If there be a point of zero density, z, on the negative curve (No. 1_v) corresponding to which a density Z' exists on the reproduction curve, the intersection of a horizontal through Z' with curve No. 3 will also determine the position of the line O'_p upon which to establish the points i_3, j_3, k_3, and l_3 which determine the D_1 values from which curve No. 1_p (dotted) is plotted. Curve No. 1_p then represents the photographic characteristics of the negative strip as used in printing and includes any failure of the reciprocity law that may occur within its range of contrast when printed in the time t_i, where $E_i = I_i \cdot t_i$.

It will be found unnecessary to actually plot curve 1_p in cases where only color coefficient or selectivity coefficient of gradient is desired This is evident from the following equations. Having plotted curves 1_v, 2, and 3, the gradient values G_{1v}, G_2, and G_3 can be obtained directly and $G_{1,p}$ can be obtained by the relation $G_{1,p} = \frac{G_2}{G_3}$, previously proven.

The selectivity coefficient of gradient $= \frac{G_{1,p}}{G_{1,v}} = \frac{G_2}{G_3 \times G_{1,v}}$.

Therefore the selectivity coefficient of gradient is given by the ratio of the gradient of the reproduction curve (No. 2) to the product of the gradient of the positive material curve (No. 3) by the visual gradient of the negative curve (No. 1). Now in case the gradient is constant these G values become equal to the gamma (γ) values, and hence, for the straight line portion of the curves,

Color coefficient = Selectivity coefficient of gradient

$$= \frac{\gamma_2}{\gamma_{1,v} \cdot \gamma_3} = \frac{\gamma_{1,p}}{\gamma_{1,v}}.$$

Also for this region

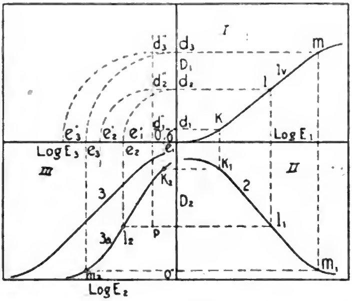
$$\gamma_{1,p} = \gamma_3 \cdot \gamma_2.$$

One other method which is very simple and direct for the determination of the color coefficient should be mentioned before closing the discussion. In fact, in practice this method has been found the most convenient for use in many cases. This method gives values of relative gradient only, and applies particularly well to those cases where both the visual and photographic curves of the negative have good straight-line characteristics. Let the intervals of $D_{1,v}$ be converted into $\log E$ intervals according to the relation,

$$d \log E = -dD.$$

and the values of D_2 obtained from curve No. 2 be plotted as ordinates on this scale. This procedure may be accomplished graphically, the method being illustrated by use of Fig. 11. The curves 1_v, 2, and 3 are plotted as in Figs. 9 and 10. Consider any series of points, *k, l, m*, etc., on No. 1. Locate the corresponding points k_1, l_1, m_1, etc., on No. 2, as indicated by the dotted lines in the diagram. The densities d_1, d_2, d_3, etc., corresponding to the points *k, l, m*, etc., are converted into a series of log *E* values by rotating the points d_1, d_2, d_3, etc., about *O* as a centre till they lie on the log E_3 scale at e_1, e_2, e_3, etc. This transformation is in accord with the relation, $d \log E_3 = -d\, D_{1,v}$, the difference between any two densities being visual density differences, since these

FIG. 11.



values are derived from curve No. 1_v, which is a visual characteristic curve. Now the intersections of the vertical lines dropped from the points e_1, e_2, e_3, etc., with the horizontal through k_1, l_1, m_1, etc., give the points k_2, l_2, m_2, etc., which, when connected, give curve No. 3*a*, as shown in the figure. In case curve No. 3 has not been plotted on a log E_2 scale correctly adjusted with respect to O'', the points d_1, d_2, d_3, etc., must first be shifted horizontally till they fall upon the vertical line through O', the position of which is determined as explained in connection with Fig. 10, and then rotated about the point O' instead of O. This is necessary in case it is desired to have curves 3 and 3*a* lie in correct positions relative to each other, but such is not necessary if values of color coefficient only are required. Means of placing curve No. 3 correctly with respect to the point O' are discussed in connection with Fig. 10 and need not be repeated here.

Now the gradient at any point on curve No. $3a$ is given by,

$$G_{3a} = \frac{d\,D_2}{d \log E_3};$$

but

$$d \log E_3 = -d\,D_{1,v};$$

therefore

$$G_{3a} = -\frac{d\,D_2}{d\,D_{1,v}}.$$

Gradient of curve No. 3 is given by

$$G_3 = \frac{d\,D_2}{d \log E_2};$$

therefore,

$$\frac{G_{3a}}{G_3} = -\frac{d \log E_2}{d\,D_{1,v}},$$

As previously shown

$$\frac{G_{1,p}}{G_{1v}} = \frac{G_2}{G_{1,v} \cdot G_3} = \frac{\dfrac{-d\,D_2}{d \log E_1}}{\dfrac{d\,D_{1,v}}{d \log E_1} \times \dfrac{d\,D_2}{d \log E_2}}$$

$$= \frac{-d \log E_2}{d\,D_{1,v}}$$

Therefore:

$$\phi = \frac{G_{3a}}{G_3} = \frac{G_{1,p}}{G_{1,v}} = \text{Selectivity coefficient of gradient.}$$

and for the straight-line portion of the curve (G = a constant) the G values become equal to the gamma values and we have

$$\chi = \frac{\gamma_{3a}}{\gamma_3} = \frac{\gamma_{1,p}}{\gamma_{1,v}} = \text{Color coefficient.}$$

In practice, unless a graphic solution is desired, curves 1 and 2 are not plotted, but the density values read from the print are plotted against the corresponding visual density values of the negative, which have been laid off on a log E scale according to the expression $d \log E = -d\,D$. This transformation is most readily accomplished by plotting the visual density values read from the negative on a log E scale laid out from right to left on the x axis and the density values from the print as ordinates. This gives the curve $3a$, having gradient of the same sign as 3, and the color coefficient is then obtained directly by the relation,

$$\chi = \frac{\gamma_{3a}}{\gamma_3}$$

In the last section of this paper, that dealing with the determination of the effective printing density, D_e and the various terms expressing the relations between the effective printing characteristics and the visual characteristics of a negative, the same symbols have been used as in the section dealing with the photographic density value D_p determined in accordance with the more rigid definition of that term. This was done in order to avoid a multiplicity of symbols, which so frequently leads to confusion. It should be remembered, therefore, that the values in the last section are understood to be of effective density, transmission, gradient, etc. All values derived from the effective printing characteristic curves, such as curves 1_p in Figs. 9 and 10 therefore depend to a certain extent upon the particular set of conditions used in the determination of those curves. If it is desired to distinguish these terms from the corresponding terms derived from the photographic characteristic curve, such as No. 1_p in Fig. 7, the subscript *e* should be used. For instance, the value of color coefficient derived as in Figs. 9, 10, and 11 strictly should be called the effective color coefficient and be designated by χ_e (Chi sub *e*), and likewise Δ_e = selectivity coefficient of effective density, and χ_e = selectivity coefficient of effective contrast, etc. It is not necessary in general, however, to adopt this nomenclature, as the nature of the term may easily be determined by a consideration of the method used in its determination.

Since these values of effective printing densities are dependent upon conditions used in obtaining them, care should be exercised in selecting the proper set of conditions if the results obtained are to be of value in estimating the quality of print that will be obtained from a given negative. It will be noted that in making the contact print from the negative strip the incident exposure E_i was specified to be of such magnitude as to just print through the highest density on the strip. Now in printing a negative the same rule is applied in general; that is, the exposure given is just sufficient to produce a barely perceptible deposit in that portion of the positive material lying under the densest image on the negative. Hence, if the highest density on the sensitometric strip is approximately equal to the highest density on the negative, the values obtained as outlined in the methods presented will apply also to the production of a print from the negative.

The authors realize that a certain degree of artificiality may exist in the definition of some of the terms discussed in this paper, but with our present knowledge of the subject it seems impossible to entirely eliminate all arbitrary assumptions. It is hoped and expected that as our knowledge of the response of the photographic surface to a given stimulus becomes more complete and precise, it will be possible to eliminate such artificiality and to formulate definitions entirely free from such objectionable factors.

In this paper no effort has been made to present quantitative data, and such statements as are given regarding the characteristics of materials should be regarded as approximate, being introduced only for the sake of illustration. Also in a general paper such as this, it is impossible to deal with all the details of the practical application of the methods discussed. Such a detailed discussion will be given in other sections of this paper, which will appear later, dealing with the application of these methods to specific cases. A very excellent example of the practical application of these methods will be found in the article on "The Sensitometry of Intensification," by Nietz and Huse, which follows this paper. A large amount of data on the spectral sensibility of positive materials and on the color coefficient of negatives produced by the use of various developing agents has already been obtained and will be presented in a later section of the series of which this paper is the first.

SUMMARY.

1. The various functions necessary for the mathematical solution of the problem dealing with the relation between the total visual transmission, T_v, and the total photographic transmission, T_p of any transmitting medium, such as a photographic negative, have been outlined. The functions being (Fig. 2):

J = Spectral energy distribution of the illuminant.
T = Spectral transmission function of the transmitting medium.
V = Visibility function of the retina.
S = Spectral sensibility of the photographic positive surface.
B = Spectral transmission function of the support carrying the transmitting medium.

2. T_v and T_p for a transmitting medium are given by,

$$T_v = \frac{E'}{E} = \frac{\text{Total transmission luminous flux}}{\text{Total incident luminous flux}}$$

$$= \frac{\int_0^\infty J_\lambda V_\lambda T_\lambda \, d\lambda}{\int_0^\infty J_\lambda V_\lambda \, d\lambda},$$

and

$$T_p = \frac{A'}{A} = \frac{\text{Total transmitted actinic flux}}{\text{Total incident actinic flux}}$$

$$= \frac{\int_0^\infty J_\lambda\, S_\lambda\, B_\lambda\, T_\lambda\, d\lambda}{\int_0^\infty J_\lambda\, S_\lambda\, B_\lambda\, d\lambda},$$

3. A method for the measurement of T_p analogous to that used for the measurement of T_v has been outlined (Fig. 3).

4. The effect of various forms of the T function upon the ratio $\frac{T_p}{T_v}$ has been discussed (Fig. 4).

5. Verbal terms approximately descriptive of the shape of the T function have been defined as follows: K being a constant:

$T\lambda = K$ (From 400$\mu\mu$ to 700$\mu\mu$)—Visually non-selective or neutral.
$T\lambda \neq K$ (From 400$\mu\mu$ to 700$\mu\mu$)—Visually selective or colored.
$T\lambda = K$ (From 280$\mu\mu$ to 500$\mu\mu$)—Photographically non-selective.
$T\lambda \neq K$ (From 280$\mu\mu$ to 500$\mu\mu$)—Photographically selective.

6. Terms relating the visual and photographic characteristics of a single deposit and of a series of deposits such as compose a photographic negative have been formulated and named as follows (Fig. 5):

(A) For a single deposit or transmitting medium,

$\frac{D_p}{D_v}$ = Selectivity coefficient of density = Δ (Delta).

(B) For a series of deposits, such as a negative,

$$G_v = \frac{d\,D_v}{d\,\log\,E} \text{ and } G_p = \frac{d\,D_p}{d\,\log\,E}$$

are the visual and photographic gradients at a given value of exposure, E.

(a) If $\frac{G_p}{G_v}$ varies with E, then

$\frac{G_p}{G_v}$ = Selectivity coefficient of gradient = ϕ (Phi).

(b) If $\frac{G_p}{G_v}$ = is constant for all values of E (or over the range of E considered) and G_p and G_v vary with E, then,

$\frac{G_p}{G_v}$ = Selectivity coefficient of contrast = K (Kappa).

(c) If $\frac{G_p}{G_v}$, G_v, and G_p are all constant for all values of E (or over the range E considered), then,

$\frac{G_p}{G_v} = \frac{\gamma_p}{\gamma_v}$ = Color coefficient = χ (Chi).

7. Methods for the determination of D_p either of a single deposit or for a series of deposits are outlined.

(*A*) A general method eliminating errors due to failure of reciprocity law and variation of gamma with wave-length (Figs. 6 and 7).

(*B*) A less general and shorter method based on assumptions that must first be proved by use of (*A*) (Fig. 8).

8. Effective printing density, D_e, is defined as a special value of the photographic density which may be slightly different from D_p as previously defined, in that values of D_e are determined by methods analogous to those used in making a contact print from a negative, and therefore are influenced by any failure of the reciprocity law and by variations of gamma with wave-length. Such values in general apply only under a certain set of conditions.

9. Methods for the determination of D_e for a series of deposits are outlined.

(*A*) An algebraic solution giving values of D_e and thus the complete effective printing characteristics of a negative (Fig. 9).

(*B*) A graphic solution giving the complete effective printing characteristic and consequently the D_e values for the series of deposits composing the negative (Fig. 10).

10. Both of the above methods involved the use of four curves.

1_p—Effective printing characteristic of the negative.
1_v—Visual characteristic of the negative.
2 —Reproduction curve (plotted from densities of contact print).
3 —Characteristic curve of positive material.

It is shown that (*G* being used as the general symbol for gradient)

$$G_{1,p} \times G_3 = G_2,$$

and that

$$\kappa = \text{Selectivity coefficient of effective contrast}$$
$$= \frac{G_{1,p}}{G_{1,v}} = \frac{G_2}{G_3 \times G_{1,v}}.$$

Or, if these terms are constant, that

$$\gamma_{1,p} \times \gamma_3 = \gamma_2.$$

$$x = \frac{\gamma_{1,p}}{\gamma_{1,v}} = \frac{\gamma_2}{\gamma_3 \cdot \gamma_{1,v}} = \text{Effective color coefficient.}$$

11. A direct method for the determination of effective color coefficient, x, is outlined (Fig. 11).

$$x = \frac{\gamma_{3a}}{\gamma_3} = \text{Effective color coefficient,}$$

where γ_{3a}, is the gamma of curve 3*a*, which is plotted directly from data obtained from curves 1 and 2, previously mentioned.

ROCHESTER, N. Y.,
October 8, 1917.

Institute for the History of Science. B. RUSSELL. (Circular letter, Patent Office Society, Washington, D. C., November 12, 1917.)—It is an admitted fact that the art of recording progress of scientific achievement in a form readily available for the use of the investigator has been developed in this country to a much less degree than in Europe. At the present time the inferiority in this important adjunct to progress in the advancement of science is fully appreciated, and within the last few months the expediency of founding an institution devoted on broad lines to this end has received considerable attention.

As outlined by Dr. George Sarton in *Science* for March 23, 1917, the history of science deals with so large a part of the intellectual development of the race that it should attract the interest of every thinking person. Such an interest is already manifest among an ever-increasing number of scientists and technicians. The field is too broad to be adequately covered by separate departments in any of our universities. This can be accomplished only by an institution devoted strictly to this purpose and adequately equipped for the great work that needs to be done. Such an institution should open its doors freely to the few who are sufficiently advanced to profit by its help, but it should not be hampered by any question of degrees or credits, remaining free to do for the advanced student what it feels will be of service in establishing the highest standards of research and scholarship.

Collateral to its efforts to increase the efficiency of the patent service, the Patent Office Society recently passed a resolution relating to a proposed Institute for the History of Science, for which a location at Washington is advocated, of the general character proposed by Doctor Sarton and others. Among the activities of such an institute recommended by Doctor Sarton are the following: (1) To offer to qualified students the best equipment for work, and the advice, assistance, and encouragement of a small corps of experts in the history of science. (2) To afford to universities, libraries, and scholars the opportunity to acquire at cost photographs of important manuscripts, documents, and objects for leisure study. (3) To offer to scientists interested in history, to historians interested in science, and to cultivated philosophers a meeting place worthy of their respect; a clearing-house where all matters of common interest to them would be centralized, examined, and eventually made known to the world. (4) To establish collections of prints, instruments, and all other early material bearing on the history of pure and applied science. This activity would in course of time expand into a department of enormous importance, as is clear to any one who has visited the Conservatoire des Arts et Metiers in Paris, the Science Museum in Kensington, or the Deutsches Museum in Munich, foundations with which we have nothing to compare in this country. (5) To publish two journals; one of a popular nature, the other of the highest scientific character.

Such an institute would not rival any department in our universities. It can and should set a higher standard of scholarship by reason of its independence, and it should be looked upon as a valuable aid by every university in the country and abroad, and as a source of supply of material which no university or library can furnish.

The Prevention of Brittleness in Electroplated Steel Springs. T. S. FULLER. (*Proceedings of the American Electrochemical Society*, October 3–6, 1917.)—One of the serious problems that confronts the makers and users of non-corroding steel springs is the brittleness produced therein during electroplating. The embrittlement is generally conceded to be caused by the nascent or atomic hydrogen which is liberated at the cathode. The fact that iron takes up nascent hydrogen at low temperatures and is made very brittle thereby was developed by a number of investigators about 1870 to 1880. Numerous researches showed that the flexibility and elasticity of iron wire and steel springs are greatly decreased by pickling, and that the effect is the more marked the thinner the material. Electrolytic iron may contain nearly 250 times its volume of hydrogen, while the commercial iron averages only one-half of its volume. Tests were made of the breaking strength of seven untreated springs; then tests were made of similar springs electrically copper plated, pickled in sulphuric acid, and tinned by dipping in molten tin and then copper plated. The pickling and the copper plating both cause brittleness, but tin dipping before copper plating is found to prevent embrittlement entirely. Steel springs may be dipped in molten tin at a temperature of 260° to 300° C. without appreciably changing their mechanical properties.

THE APPLICATION OF MECHANICAL DIFFERENTIATION TO ENGINEERING PROBLEMS.

BY

ARMIN ELMENDORF, M.Sc.,
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In its application to engineering problems, mechanical differentiation is almost always concerned with determining acceleration so that the latter may be substituted in some equation connecting it with force and mass. The significance of the law that force is equal to the product of mass into acceleration cannot be overemphasized. Every object in motion, be it a ball, projectile, automobile, or locomotive—in fact, whatever has mass, and hence every conceivable body—pursues its path in absolute accord with the dictates of this law. A street car is either increasing its speed, running at a constant speed, or is being decelerated. Each of these motions is the result of the simultaneous action of several external forces. The resultant force at the tread of every wheel may be resolved into a vertical and horizontal component. The total vertical or upward force is equal to the total downward force or the weight of the car; hence, there is no motion in this direction. On the other hand, the resultant of all the horizontal forces acting on the car may be acting forward, so that it acquires motion, and this motion is continually increased until the horizontal forces balance, when the car proceeds at a constant or uniform speed. Finally, if the sum of the forward or impelling forces is less than the sum of the retarding forces, the speed falls off until motion ceases. In every instance the resultant force acting on the car, producing a change in its speed, is equal to the product of the mass of the car into its acceleration.

TRAIN RESISTANCE.

The illustration of the street car is particularly pertinent in that it suggests an engineering problem whose solution will be enhanced by mechanical differentiation; namely, the problem of train resistances. Many tests have been made to determine train resistance, but these have always depended upon direct-force readings from a dynamometer connecting the locomotive with the train. Inaccuracies seem to be inseparable from such tests. It is troublesome to obtain the grade of the track for any considerable distance, which, if it is not taken into consideration, must necessarily introduce error, because a grade either demands an increase in the draw-bar pull, or, in the case of descent, it diminishes the pull. Secondly, the readings being taken by observers on the train, the changes in speed cannot be known, so that the force required to accelerate the train is read in with the draw-bar pull as train resistance.

A resort to the purely kinematical relations of distance, velocity, acceleration, and time has been suggested, eliminating entirely all direct measurements of force. By allowing the car to coast upon a section of level track, the distance-time, or even the speed-time, curve may be obtained with suitable instruments. A double differentiation of the former curve with a differentiating machine or a single differentiation of the latter yields the acceleration-time curve, and all that remains to be done to find the total car resistance at any instant is to multiply the mass of the car by the acceleration at that instant. Then, by referring back to the speed-time curve, the speed at the same instant may be learned, and from these data a speed-resistance curve could be drawn. Such information is especially valuable for curves in the track. The civil engineer must know curve resistance in laying out a road, to be able to establish permissible grade.

The beauty of an investigation on the order of that outlined is that another item of great importance may be studied; namely, power consumption. What is the actual horsepower consumed in train resistance? Technical terminology defines power as work per unit of time. The foot-pound per second, as well as the horsepower, is a unit of power. Knowing the total retarding force at any instant and the velocity at the same instant, it is only necessary to multiply the two to obtain power consumption at that instant due to train resistance. If the unit of force is the pound and of velocity a foot per second, then the product of force into velocity gives power in foot-pounds per second, which, divided by 550, gives horsepower. Hence a power-consumption speed curve could be obtained.

ELECTRIC CAR EFFICIENCY.

Another problem bearing on rolling stock is the determination of the horsepower of an electric car under starting conditions, and its efficiency as a machine under the same conditions. Taking the ordinary definition of efficiency as the ratio of useful power or power output to power input, we see that for the electric car as a machine, useful power is the power not expended in overcoming friction, hence available to pull trailing cars or for acceleration, while the latter is the total electrical power delivered to the motors. Efficiency is thus also a measure of the ability of the car to pick up speed under a certain power consumption. Clearly, vehicle efficiency defined in this way would be zero when the car is running at a constant speed. Contrary to the usual efficiency relations, the efficiency of a vehicle of this kind would probably be a maximum soon after starting instead of near its highest speed as with most machines used for motive purposes.

To determine vehicle efficiency it is necessary again to resort to the kinematical relations existing between speed, acceleration, and time. By mounting a sensitive speedometer on the car and reading it at definite small time intervals while the car is "getting up speed" the data for a speed-time curve could be obtained. A record of power consumption must also be taken from the wattmeter. Then, differentiating to get the acceleration curve, and proceeding from it through the force-velocity relations, we arrive at "useful power." The ratio of this power to that given by the meter would be vehicle efficiency. From it any efficiency-speed curve could be drawn for any setting of the starting control. The total power delivered to the motors, it will be seen, is thus consumed in overcoming friction (internal, track, and air resistance), in accelerating the car, and in heat loss in the armature.

Correction for rotating parts would have to be made, but this presents no great difficulty. The only step that must be taken is the determination of the moments of inertia of the rotating parts, which could be done experimentally or approximately computed. Besides being given a translatory acceleration, these machine parts are given a rotational acceleration, which also consumes power. The relation between torque, T, angular acceleration, α, and moment of inertia, I, about the axis of rotation is given by the equation, $T = I\alpha$. The angular acceleration and moment of inertia being known, the corresponding torque may be computed. If n is the speed of rotation in revolutions per second, the power, P, is expressed by the equation $P = 2\pi Tn$, which is the instantaneous power required to produce the angular acceleration, α, corresponding to any particular speed of rotation, n.

AUTOMOBILE EFFICIENCY.

In an automobile considered as a machine, the power input would be the brake horsepower of the engine, and the useful power would be the same as that of the electric car; namely, the power available for acceleration. The former is not known, since we are not certain that the running conditions, when mounted in the automobile, are the same as those when the engine is on the test-block. Neglecting the slight difference in power lost in the gears due to difference in power transmitted when running idle and under full load, we may determine many interesting features of automobile performances. A coasting run on a level and smooth road will give all the data for the determination of the total friction power at various speeds, the problem being identical to that outlined for train resistance. Now, starting the automobile over the same road and under the most effective starting conditions in regard to throttle and spark control will furnish the data for the useful or acceleration power curve. The sum of the two is engine power at the clutch, and the ratio of the useful power to the total power is the automobile efficiency. Efficiency curves could be drawn for various combinations of throttle and spark.

ROAD RESISTANCE TO TRAFFIC.

By allowing an automobile to coast over various road surfaces and drawing up the resistance curves as before, valuable information could be obtained upon the power consumed in travelling over the different surfaces. Possibly road taxes could be justified in this way.

AIR RESISTANCE TO FLIGHT.

The resistances to flight of aeroplanes of different designs merit considerable study. Experiments upon models placed in "wind-tunnels" through which a blast of air is sent by artificial means can give only approximate results on account of the miniature size of the models and the confinement of the air currents set up by the obstruction. The need for information on full-size machines in flight is evident.

By means of two transits, one for observing horizontal displacements of a gliding aeroplane, and the other for noting changes in altitude, all the data for the distance-time curve may be obtained. Proceeding from it through double differentiation to the acceleration-time curve, and then to the power curve due to changes in altitude, some of the most valuable data concerning airplane performance become available; namely, the power necessary to overcome head resistance under various speeds.

STRESSES IN BEAMS, GIRDERS, AND SLABS.

The branch of mechanics covered by the strength of materials furnishes several important technical problems whose solution may be enhanced by mechanical differentiation. Due to the indeterminate nature of wall loading, for example, theoretical stress computation can yield only approximate results. If, however, instead of starting with the loading, we arrive at the external or bending moment at any section of a girder through differentiation of the deflection curve, greater certitude attaches to the stresses determined. The actual stresses computed in this way may be compared with the theoretical stresses.

Since the second derivative measures the rate of a rate, it measures curvature, and, in the case of beams, curvature indicates bending and stresses. The lowering of the neutral axis of a girder relative to its position in the unloaded condition is readily determined, so that the deflection curve is known and may be plotted to an enlarged scale of ordinates. Subsequent to the double differentiation involved, no particular difficulty should be encountered. Remembering the relation between external or bending moment and stresses expressed by the flexure formula, and the relation between the former and curvature, we have

$$M = \frac{SI}{c} = EI\frac{dy^2}{dx^2} \quad \text{or}$$

$$S = Ec\frac{dy^2}{dx^2} \qquad \text{where}$$

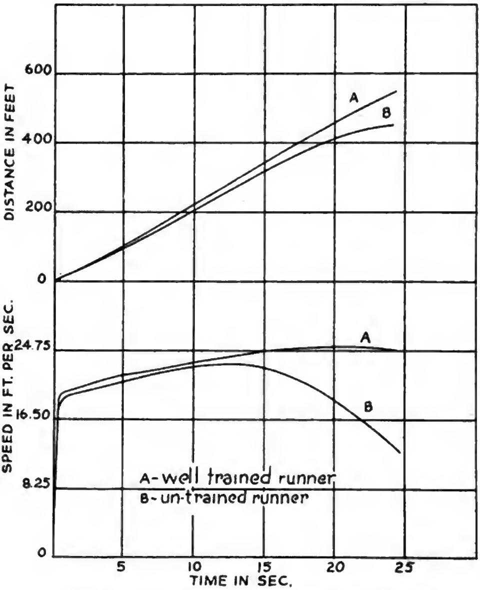
M = External or bending moment at the section under consideration.
S = Stress in the outermost fibre, hence the maximum stress in the section.
I = Moment of inertia of the section.
c = Distance from the neutral axis to the outermost fibre.
E = Modulus of elasticity of the material.
y = Deflection.
x = Distance along the neutral axis.

It will be seen that this solution may also be applied to the vexing problem of flat slabs, since the troublesome and unknown moments of inertia fall out entirely.

MUSCULAR POWER OF THE HUMAN BODY.

From tests conducted upon students performing various exercises, the author was able to compare graphically the power and endurance of men whose physical training varied over wide limits.[1] Distance-time curves were obtained for running uphill, weight-lifting, and swimming. A single differentiation yielded the speed curves. In the case of the men running uphill vertical speed multiplied into the weight of the runner gave this external power. The maximum attained by any one runner over a distance of 500 feet up a 10 per cent. grade was a little more than

FIG. 1.



Development of endurance or power curves for men running uphill.

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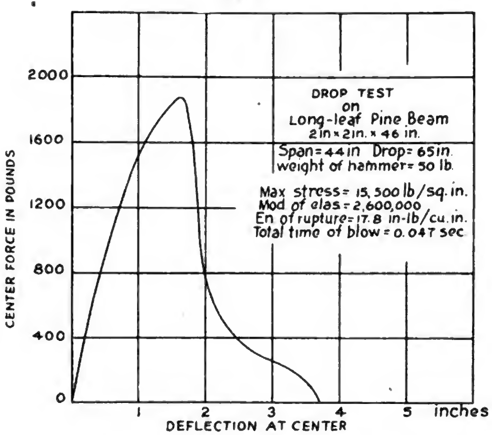
[1] *Scientific American Supplement* for August 11, 1917.

three-quarters horsepower. Typical endurance curves developed in this way are shown in Fig. 1.

STRESSES IN IMPACT.

In a series of impact tests conducted at the United States Forest Products Laboratory at Madison, Wis., in 1915, upon timber beams, by dropping a 50-pound weight upon the centre of the beam in a Hatt Turner impact testing machine, the author obtained deflection-time curves for a number of beams broken by a single blow. The second derivative of these curves yielded acceleration which, substituted in the formula

FIG. 2.



Force-deflection curve for a timber beam in impact.

$$F = W_t - \left(W_t + \frac{17}{35} W_b\right) \frac{1}{g} \frac{ds^2}{dt^2}$$

gave the forces to plot force-time curves. In the equation, F is the centre force, W_t the weight of the tup, here 50 pounds, W_b is the weight of the beam, and s is vertical displacement. By scaling the forces corresponding to each deflection, the force-deflection curves for impact loading were drawn, and by substitution in the flexure formula the maximum stresses set up in the beam by the blow were obtained.[2] A typical impact force-deflection curve is shown in Fig. 2.

VALVE MOTION.

Innumerable cases arise in machine design in which it is desired to know the magnitude of forces that will produce certain motions. One of these is given by the valve stem in a high-speed engine. The size of the spring necessary to avoid hammering by keeping the follower in contact with the cam is wanted. On account of the extremely small motions these must be greatly magnified, and this introduces some error. However, the author has obtained results in the double differentiation of displacement-time curves that agree very well with theoretical results for the particular cams investigated.

MADISON, WISCONSIN, September, 1917.

Toluol from City Gas. ANON. (*The Iron Age,* vol. 100, No. 21, p. 1275, November 22, 1917.)—In anticipation of the present national emergency, there has been going on without any publicity a development in toluol manufacture which bids fair to be of the utmost importance to the nation in the supply of trinitrotoluol. Early in 1915, the Koppers Company of Pittsburgh, which at that time was building a large number of by-product coke plants, and in connection with which it was also building benzol and toluol plants, started in the laboratories of the Mellon Institute, Pittsburgh, an investigation into the recovery of toluol from carburetted water gas, the gas made in all large cities of the country by the gas companies for domestic use.

It has been found that every by-product coke oven plant in the country is producing or has arranged to produce toluol to the utmost capacity, and that the remaining needed toluol must be secured from city gas. The Pittsburgh By-Product Coke Company, an operating company associated with the Koppers Company, has carried out a plan in conjunction with the gas-light company at Washington to erect the first plant at the West station of that company to effect the removal of toluol from 5,000,000 cubic feet of carburetted water gas per day. This plant was placed in operation on July 14, 1916, and has yielded since that date 200,000 gallons of toluol. While this plant was the first to use this process, and many improvements increasing the efficiency and economy of operation have been introduced, it proved a commercial and technical success, equalling the results promised by laboratory methods. Many of these "stripping" plants are in operation in various cities, and others are in preparation.

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[2] JOURNAL OF THE FRANKLIN INSTITUTE, December, 1916.

NOTES FROM THE RESEARCH LABORATORY, EASTMAN KODAK COMPANY.*

PHOTOGRAPHIC RESOLVING POWER.[1]

By Kenneth Huse.

[Abstract.]

Photographic resolving power is defined in terms of the distance by which two minute images lying adjacent to one another must be separated in order that, when photographed, they may be distinguishable as separate images and may not merge into one in consequence of the grain structure of the emulsion.

The object of this investigation was to determine the influence of the specific factors, exposure, development, and wavelength of light on photographic resolving power.

The method employed consisted of photographing a fan-shaped converging grating in a reducing camera, fitted with a highly corrected telescopic objective. The measurements of the minute images thus formed were made on a micrometer microscope. Since the spacing of the grating and the scale of reduction are known, a numerical expression for resolving power is found. The sensitive material used was Seed Lantern plates.

The errors involved in the method, due to the use of a lens and to the fact that the measurements introduce the personal equation to a certain extent, are proved negligible.

The results of experiments on the effect of exposure show that resolution is extremely sensitive to this factor, there being a critical value where best resolution is manifested, serious over- or under-exposure being detrimental. It was also found that there is an optimum time of development for best resolution, so that it seems that an exposure such that the densities lie on the straight-line portion of the characteristic plate curve, and development to a gamma of unity, yield highest resolving power.

Investigation showed that the reducer or the developer employed had great bearing on resolution. Twenty developers were

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* Communicated by the Director.

[1] Communication No. 61 from the Research Laboratory of the Eastman Kodak Company, published in *Journal of the Optical Society of America*, July, 1917, p. 119.

investigated. The results obtained showed variation in resolution values varying from 47 to 77, due to the developer.

With regard to the effect of the wave-length of the incident light, resolution was best for light of short wave-lengths, the resolution decreasing to a minimum in the green and increasing again in the red, though not to as high a value as with blue light. In these experiments three types of photographic emulsions—ordinary, orthochromatic, and panchromatic—were used.

The Belgian Coal and Coke Industry. ANON. (*Coal Age*, vol. 12, No. 17, p. 713, October 27, 1917.)—During the years that immediately preceded the war, Belgium produced, in round figures, 24,000,000 metric tons of coal a year. About 1,350,000 tons of this was coked, yielding a trifle more than 1,000,000 tons of commercial coke, including breeze sold for domestic use. All coke was, of course, by-product coke, as none other has been made in Belgium since 1892 or 1893.

Belgium was a pioneer in the by-product industry. The oldest by-product company now in existence is the Société Anonymé du Charbonnage des Produits, at Flénu, Belgium, which was incorporated in 1856 for the mining of coal and the manufacture of by-products. That company may have become better known abroad as a coal company than as a by-product concern, but this was due to the extraordinarily fine natural condition of its coal deposits, which enabled the company to pay big dividends earned in mining and selling coal while meeting the stress of developing the by-product department of its business. Regardless, however, of the trying period of development, the Produits Company never ceased for a single day, since 1856, to make by-products; and the first aniline colors ever put on the market were made at Flénu by this company at a time when its coke and by-product department was managed by the noted Belgian chemist Neyrincks.

With the advent of the Coppée vertical-flue coke oven, the Produits Company became a decided factor in the by-product industry. That was about 1870, at a time when Germany had only beehive coke ovens and when all coke made in Belgium was produced in retort ovens of the original Coppée design. Not only was Germany later than Belgium in eliminating its beehive ovens, but even to this day there is not in Germany a single coke oven which is not of the vertical-flue kind first invented by Coppée, a Belgian, or the horizontal-flue type developed by Solvay and Semet, the former a Belgian, the latter a Frenchman, both living to-day. Many persons in this country believe, even among those of the by-product industry, that the by-product oven is of German origin and development. To this day the Belgium coke ovens have always kept at least one step ahead of all others.

NOTES FROM THE PHYSICAL LABORATORY OF THE UNITED GAS IMPROVEMENT COMPANY.*

A NEW NEUTRAL TINT AND A VARIABLE TINT SCREEN.

By E. Karrer.

A NEUTRAL tint screen has been constructed using small glass bars, between which is laid a very thin layer of some black opaque material. The screen has a very high maximum transmission, determined only by the transmission of the optical glass used to make the bars and the thickness of the interposed opaque material. The screen may also be made into a variable tint screen by replacing the opaque material by some colored transparent medium. As the angle between the screen and the incident beam of light is altered, more of the light is cut out by the opaque screen in the first case, and a greater portion of the light is transmitted through the colored medium in the second case.

A CONVENIENT LABORATORY CONDENSER FOR EXPERIMENTAL PURPOSES.[1]

By E. Karrer and H. S. Newcomer.

A CONDENSER for use in spectroscopy with the spark is described, in which pyrex glass beekers are used as the dielectric, immersed in a salt solution for the conductor. The performance of the condenser has been found for this purpose to be very satisfactory.

ON THE LUMINESCENCE OF RADIOACTIVE MATERIALS.[2]

By E. Karrer and D. H. Kabakjian.

A STUDY of the luminescence of phosphorescent zinc sulphide when excited by radioactive substances has been made and a more detailed study of the general phenomena of luminescence of materials due to radioactivity has been carried out. The decay curves (brightness *vs.* time) have been plotted for many samples of luminous substances. A series of curves of this character has also been made where the percentage of the radioactive material has been changed. The temperature effects upon the luminescence have been studied. The results seem to be in more general accord with Rutherford's theory than shown by previous workers. Certain new applications of the luminescence of these radioactive materials will be given in the near future.

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* Communicated by the Manager.

[1] In collaboration with the Phipps Institute, University of Pennsylvania.

[2] In collaboration with the Physical Laboratory, University of Pennsylvania.

THE APPLICATION OF GRAPHICS TO GAS MIXTURES.

By Edward J. Brady.

TRILINEAR coördinates to express the characteristics of alloys consisting of three different metals were first used by Professor Thurston in 1877.

For a better illustration of their value, we may cite their use in the theory of color where any integral color may be represented by a point on a triangle, each corner representing 100 per cent. of one of the three primary sensations.

The fact that this method of graphical representation can be admirably applied to the determination of the characteristics of gas mixtures seems to have been overlooked.

In a mixture of three gases the heating value of the mixture is equal to the sum of the products of the percentage of each constituent multiplied by its respective heating value. This is also true of specific gravity, as well as the amount of air necessary for complete combustion.

It follows from the above that if on each of the three corners of a "gas mixture triangle" we erect perpendicular lines proportional to the heating value of the constituent at that corner, the upper ends of these lines will determine a plane. This plane, which we may call the heating value plane, will, in general, make an angle with the plane of the paper. Contours, or lines of equal heating value, drawn upon this plane will be straight parallel lines, making angles with the sides of the triangle, depending upon the heating value of the particular gases mixed. Such lines are the loci of an infinite number of mixtures of the three gases represented, all having the same heating value.

Similar systems may be drawn for specific gravity and air required for complete combustion.

The latter system will, in general, be almost parallel with the heating value contours, because of the fact that heating value is roughly proportional to the number of O_2 atoms required for complete combustion.

Specific gravity contours or lines of equal gravity generally cross the heating value lines at certain angles. It is thus possible to eliminate one of these variables from experiments on gas mixtures.

Travelling along one of the gravity contours changes the heating value but not the gravity, and *vice versa.*

These lines are all straight because of the linear relation between the particular characteristics so chosen, viz., heating value, gravity, etc., and the quantity of gas involved.

However, other characteristics of the mixture may also be represented, as velocity of inflammation by curved lines.

The "gas mixture triangle" is not limited to pure gases. We may determine the characteristics of such gases as coal gas, water gas, and oil gas in the ordinary way, using these values to construct a triangle, and proceed as above. The quality of a mixture may be decided upon and its position on the diagram located at a point. A circle drawn with the point as a centre will establish a tolerance outside of which the mixture must not fall. Other uses will suggest themselves.

The Effect of Mouthpieces on the Flow of Water Through a Submerged Short Pipe. F. B. SEELY. (*University of Illinois Bulletin,* No. 96, April 30, 1917.)—A knowledge of the extent of the loss due to contraction or expansion of a stream is of considerable importance in a variety of hydraulic problems. Comparatively little experimental work has been done to determine the value of conical mouthpieces of various angles and lengths in reducing the entrance and discharge losses of a submerged pipe, particularly for mouthpieces of the sizes and proportions comparable with those met in engineering practice. For example, it may be possible, by due attention to the shape and angle of connections and intakes, to increase the flow through the suction and discharge pipes of low-head pumps, through large valves, and a number of other hydraulic devices.

Losses from this cause are difficult to estimate and easy to overlook. Even where such losses are in themselves of little consequence as compared with other quantities involved, they may have a considerable influence upon subsequent losses on account of the turbulent motion started by the contraction or expansion. The flow of water usual in engineering practice is more or less turbulent. The general equation of energy, or Bernoulli's theorem, so generally used in hydraulics, applies only where the particles of water move with uniform velocity in parallel stream-lines. Although this condition of flow seldom occurs, satisfactory analyses may often be made by using an average velocity and introducing empirical constants. However, a very slight change in the conditions under which flow takes place may cause, in some cases, a large difference in the action or behavior of the water. There is, therefore, always danger in extending the use of experimental data or empirical constants to apply to conditions of flow quite different from those under which the data were obtained.

To determine the losses of head under varying conditions of flow, a tank with a partition forming two compartments was used. A cast-iron short pipe, 22½ inches long, of 6 inches bore, was attached by a flange near the middle to the partition separating the two compartments of the tank, allowing the pipe to project into each compartment. This tube was threaded at each end so that a mouthpiece could be screwed on either end or both ends. The cast-iron conical mouthpieces which were screwed at the ends of the 6-inch pipe were, at the small ends, of the same cross-sectional area as the pipe with varying angles of flare.

As applying to conditions likely to be met in engineering practice, taking h = total head, h^1 = loss of head at entrance, v = mean velocity in the pipe, and, c = coefficient of discharge:

(*a*) In an inward projecting tube (no mouthpiece): $h^1 = 0.62\ v^2/2g$ instead of $0.93\ v^2/2g$ as usually assumed, giving $c = 0.785$ instead of 0.72 as given in $h^1 = (1/c^2-1)\ v^2/2g$. Flush tube (square entrance): $h^1 = 0.56\ v_2/2g$ instead of the customary $0.49\ v^2 2g$, with $c = 0.80$ instead of 0.82, as given by nearly all authorities.

(*b*) In an inward projecting tube with conical mouthpiece: h^1 may be as low as $0.165\ v^2/2g$ if the flare is between 30 and 60 degrees (angle with axis), with an area ratio of mouthpiece to pipe between 2 and 4, and the value of $c = 0.915$.

(*c*) For mouthpieces with a flare of 20 to 90 degrees and area ratio to 4: $h^1 = 0.20\ v^2/2g$, and there is little advantage in making an entrance mouthpiece longer than corresponds to an area ratio of 2 and a flare angle greater than 10 degrees.

(*d*) The amount of velocity head recovered at the discharge end decreases rather rapidly as the angle of divergence increases from a total angle of 10 to 40 degrees. At or near 40 degrees the velocity head recovered falls approximately to zero.

(*e*) A conical discharge mouthpiece with a total flare angle of 10 degrees and area ratio of 2 will recover 0.435 of the velocity head in the pipe, which is 58 per cent. of the theoretical amount possible of recovery.

(*f*) An entrance mouthpiece tends to promote smooth flow in the pipe, and greater velocity head recovery is possible when the pipe is provided with mouthpieces at both ends.

THE FRANKLIN INSTITUTE.

(Proceedings of the Annual Meeting held Wednesday, January 16, 1918.)

HALL OF THE FRANKLIN INSTITUTE,
PHILADELPHIA, January 16, 1918.

PRESIDENT DR. WALTON CLARK *in the Chair.*

Mr. Charles E. Bonine, Acting Chairman, Committee on Science and the Arts, reported the condition of the work of the Committee.

The tellers of the election, Messrs. Jennings, Colvin, and Picolet, submitted the report of the ballots cast for President, Vice-president, Treasurer, and members of the Board of Managers, and the following gentlemen were declared duly elected to the respective offices:

Walton Clark, President (to serve one year).

Louis E. Levy, Vice-president (to serve three years).

Cyrus Borgner, Treasurer (to serve one year).

Charles Day, Kern Dodge, Alfred W. Gibbs, George R. Henderson, George A. Hoadley, Isaac Norris, Jr., Lawrence T. Paul, James S. Rogers, Managers (to serve three years); Gellert Alleman, Manager (to serve two years).

The President presented a statement of the work of the Institute for the fiscal year ending September 30, 1917, with the reports of the various committees of the Institute and Board of Managers.

Doctor Hoadley, on behalf of the Committee on Science and the Arts, introduced Mr. Max Levy, of Philadelphia, to whom had been awarded the Edward Longstreth Medal of Merit for his Hæmocytometer.

The President presented the Medal and accompanying document to Mr. Levy, who thanked the Institute for the honor conferred upon him.

The paper of the evening was presented by W. P. Mason, M.D., LL.D., Professor of Chemistry, Rensselaer Polytechnic Institute, Troy, N. Y. The lecturer pointed out the dangers that arise from faulty camp construction and regulation, whether the occupants be soldiers or laborers. These dangers may not be confined to those in the camp, but may extend to distant communities in the same general district. Consideration was given to methods for caring for fecal material; horse manure; kitchen refuse and general garbage; fly-transmission of disease; incineration and types of incinerators; policing of camps; protection of watersheds; protection of camp sites; camp water supplies; portable laboratories for water analysis; European army standards for water; sterilization and related sanitary problems. The subject was illustrated by lantern slides.

After a discussion, the thanks of the meeting were extended to the speaker. On motion, duly seconded, the thanks of the Institute were also extended to the tellers of the election for their services.

Adjourned.

GEORGE A. HOADLEY,
Acting Secretary.

REPORT OF THE PRESIDENT

FOR THE FISCAL YEAR ENDING SEPTEMBER 30, 1917.

To the Members of The Franklin Institute:

I am instructed by your Board of Managers to report to you upon the Institute's work during the Institute year last past. This writing is the report.

It is impossible to write any story of accomplishment during the year just past without frequent reference to the great event of that year—the entry of the United States into the world war. And this because, in the United States, there is no individual or institutional work of any moment that has not been affected profoundly by the war.

The Franklin Institute and its work have been affected in various ways. The war has taken from the Institute three of its Managers—Mr. Charles Day, chairman of the Committee on Sectional Arrangements, now, as a member of the Army War Council, doing important work for the Government; Mr. William Chattin Wetherill, chairman of the Committee on Science and the Arts, now an ensign in the Aviation Section, U. S. Navy; and Mr. Theobald F. Clark, now an artillery captain. The war has taken our Secretary, Dr. R. B. Owens, now a major in General Pershing's force; our Science and Arts Assistant, Mr. T. N. Parrish, now a lieutenant of the Signal Corps. The work of the Institute has not ceased in any department because of the absence of these gentlemen. The work of the Secretary has been taken over, and is being ably performed, by Dr. George A. Hoadley, a member of the Board; and other of the work heretofore done by members now gone to war is being covered by other members who have volunteered for the purpose. We sadly miss our absent associates; we wish them a safe and early return to the duties of civil life, and in the interim we increase our efforts to maintain the Institute in useful operation.

The Managers of the Institute, this year, as from the beginning, while conducting the routine work committed to them, have purposed to maintain for the Institute such a reputation for efficiency and for patriotism as would mark it as a potential force available to the nation in time of distress. Your Board are gratified to be able to say to you that we have the evidence of this reputation in the number of demands that the departments at Washington have made upon us since the entry of our country into war, each of which has been promptly honored.

At the request of the War Department, the Institute initiated and is now conducting a school in wireless telegraphy, with about one hundred and twenty students. These are young men subject to draft, and qualifying themselves for the operation of modern devices for the transmission of information on the battle-field. The Institute, through its executive officers, has had a part in the formation of schools of navigation and of marine engineering, now being conducted successfully in this city, and already accredited with some hundreds of graduates. These schools were started at the request of the United States Shipping Board. The School of Navigation was opened in the Institute. As requested by the War Department, we established and maintained a recruiting and examination station for applicants for admission to the aviation service. Upon Government request we have made studies of the state of various arts concerned with the conduct of a war. Though thus called upon to undertake these emergency duties, the regular work of the Institute has progressed about as usual.

More detail of the work of the year is set out in the reports of the committees, attached hereto, and to be printed in full in the 1918 Year Book. I extract from these reports as follows:

The Library Committee, Mr. Morgan, chairman, reports additions to the Library totalling 2364. It is interesting to read in this report that among our current magazines two have suspended publication and fifty-six have been discontinued temporarily because of war conditions. The contents of the Library are given as—

Volumes, bound and unbound	71,020
Pamphlets	28,845
Maps and charts	2,888
Photographs	1,336

The committee again calls attention to the importance of binding the present unbound volumes. More or less volumes are bound every year, but there are at present some 2800 needing binding. We need more funds for this purpose. The committee reports difficulty in obtaining sufficient office assistants.

The Committee on Museums, Mr. Outerbridge, chairman, reports a number of interesting additions to our group of models and historic apparatus.

The report of the Committee on Meetings, Mr. Rogers, chairman, is a record of the stated meetings held and contains an interesting report of the presentation of the Franklin Medal, at the May meeting, to Dr. Hendrik Antoon Lorentz, F.R.S., of the Royal Academy of Sciences, Amsterdam and the University of Leiden, and to Dr. David Watson Taylor, Chief Constructor of the United States Navy.

The report of the Committee on Stocks and Finance, Mr. Forstall, chairman, contains a list of the funds held by the Institute, the receipts during the year, and the expenses of operation. I quote the last paragraph of the report entire, as follows:

"The total increase since last year in the principal of all funds amounts to $129,308.22; of which the principal items are the John H. Wahl Fund of $79,146.53, the increase of $23,615.04 in the General Endowment Fund from subscriptions received to meet the conditions of the Wahl bequest, and an increase of $10,284.32 in The Franklin Institute Building Fund. With the John H. Wahl Fund was received $9637.96 of accumulated income, and this accounts for the large surplus shown, which enabled a reduction of $7250.00 in 'Bills Payable.'"

The Building Fund has grown very little during the year. It amounts to $461,000, of which sum $209,000.00 is invested in nine buildings and lots at the corner of Race and Nineteenth Streets. (Since the close of the fiscal year covered by this report of the Finance Committee we have added another house and lot to our holdings on this site at a cost of $18,000.)

There will be no effort during the war to raise the additional funds necessary to the erection of a building better suited to our purposes. In the meantime this dignified old structure lacks little but in size and location of being a proper home for an institution of our character. And it has honored traditions that a new building will hardly accumulate in two generations.

In general, the financial affairs of the Institute continue to be in a satisfactory condition.

The report of the Committee on Sectional Arrangements, Mr. Day, chairman, gives a list of the twenty-one lectures delivered before the Sections—frequently in joint meetings with the Philadelphia branches of national engineering societies.

The report of the Committee on Science and the Arts, Mr. Wetherill, chairman, is a statement of the activities of the committee during the year and shows that the standards of the committee are being well maintained. Fifty-nine subjects were considered and twenty-five awards were recommended.

The Committee on Instruction, Mr. Paul, chairman, renders its annual report covering the 93d year of the Franklin Institute School of Mechanic Arts. The courses in Mechanics and in Naval Architecture were extended beyond the standard of previous sessions; the interest in Naval Architecture has naturally increased. The graduating class of 1917 contained 41 members. The total number of students enrolled was 372—an increase of twenty-one per cent. over the previous year. During the current year—not covered by this report, which is for the year 1916–17—the work of the schools has been greatly extended, and the committee's labors and responsibilities have been correspondingly increased.

The Committee on Exhibitions, Mr. Chambers, chairman, reports no activities during the year.

The Committee on Elections and Resignations of Members, Mr. Gibbs, chairman, reports the election of—

Resident members	58		
Non-resident members	57		
Associate members	8		
Life members	1		
Total			124
The resignation of—			
Resident members	14		
Non-resident members	15		
Second class stock members	1		
Total		30	
The death of—			
Resident members	7		
Non-resident members	9		
Second class stock members	3		
Honorary members	3		
Total		22	
Total of resignations and deaths			52
Gain in membership—all classes			72

Our membership grows slowly. We are not very good advertisers, and knowledge of the value of the Institute's work is not forced upon the community. We do not conduct campaigns for membership or for funds. Doubtless we will attract a larger membership when we are domiciled in a more prominent and popular location.

Members of The Franklin Institute, your Board of Managers still believe they are justified in reporting to you that the work of your Institute continues to be good. While those of your elected representatives who were of suitable age and condition have gone to meet your country's foes, those of us who are so conditioned as to be unable to make this supreme sacrifice have endeavored, in our less heroic field, to meet the new conditions and to continue the Institute as an efficient and ever-ready aid to the State, now in war, as for nearly a century in peace. This is our Institute's highest function, and it will spare no effort necessary to its full performance.

Respectfully submitted,
The Board of Managers,
WALTON CLARK,
President.

PHILADELPHIA, January 16, 1918.

COMMITTEE ON SCIENCE AND THE ARTS.

(*Abstract of Proceedings of the Stated Meeting held Wednesday, January 2, 1918.*)

HALL OF THE FRANKLIN INSTITUTE,
PHILADELPHIA, January 2, 1918.

MR. CHARLES E. BONINE, *Chairman pro tem.*

The following report was presented for first reading:

No. 2704.—Sweetland Filter Press.

The following reports were presented for final action:

No. 2701.—Talbot Air Lift. Recommended that the Edward Longstreth Medal of Merit be awarded to Levi Talbot Edwards, of Philadelphia, Pa.

No. 2703.—Sweetland Filter Cloth. Recommended that the Certificate of Merit be awarded to Ernest J. Sweetland, of Upper Montclair, N. J.

GEORGE A. HOADLEY,
Acting Secretary.

SECTIONS.

Section of Physics and Chemistry.—A meeting of the Section was held in the Hall of the Institute on Thursday evening, December 13, 1917, at 8 o'clock, with Mr. George R. Henderson in the chair. The minutes of the previous meeting were read and approved.

A. V. Bleininger, Ceramic Chemist of the U. S. Bureau of Standards, Pittsburgh, Pa., presented a paper, entitled "Some Industrial Problems in Silicate Technology." Among the subjects discussed was the manufacture. in the United States, of refractories, optical glass, spark-plug porcelain, and glass pots of porcelain. The manufacture of such pots by moulding, with and without the use of a vacuum, was described.

Doctor Hoadley, Messrs. Henderson and Fulweiler, and others participated in the discussion. On motion of Mr. W. H. Fulweiler, a rising vote of thanks was extended to Mr. Bleininger. The meeting then adjourned.

JOSEPH S. HEPBURN,
Secretary.

MEMBERSHIP NOTES.

CHANGES OF ADDRESS.

LIEUT. COMMANDER A. W. K. BILLINGS, care of Commander U. S. Naval Forces, Paris, France.

CAPTAIN H. E. IVES, Signal Corps. U. S. R., 1023 Sixteenth Street, Washington, D. C.

DR. GUSTAV LINDENTHAL, 25 Church Street, New York City, N. Y.

MR. LAWRENCE T. PAUL, 202 Liberty Building, Broad and Chestnut Streets, Philadelphia, Pa.

MR. CARL D. ULMER, Minnesota By-Products Coke Company, St. Paul, Minn.

NECROLOGY.

John Price Remington was born in Philadelphia, March 26, 1847, died on January 1, 1918.

He was educated in the Friends' School and the Central High School of Philadelphia, and later entered the Philadelphia College of Pharmacy, graduating in 1866. In 1868 the degree of Master of Pharmacy was conferred upon him by his Alma Mater, and in 1899 the Northwestern University conferred upon him the degree of Doctor of Pharmacy.

Doctor Remington was made Professor of Pharmacy of the Philadelphia College of Pharmacy in 1874, and from 1877 to 1915 was director of its Pharmaceutical Laboratory. In 1893 be became Dean of the College, and had served in that capacity since that time. He had been a member of the Revision Committee of the U. S. Pharmacopœia since 1880, and was chairman of the committee since 1901. He acted as editor of the editions of 1890, 1906, and 1913.

He was president of the First International Pharmaceutical Congress, 1893, and a delegate to the Pan-American Medical Congress, which convened in Washington in the same year.

Doctor Remington was a member of the leading scientific societies of the world. His work, "Practice of Pharmacy," has had wide circulation. He had also acted as editor of the United States Dispensatory of 1883 and nineteen later revisions, and Lippincott's Medical Dictionary, 1897.

Doctor Remington became a member of the Institute in 1880.

LIBRARY NOTES.

PURCHASES.

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BINGHAM, CHARLES.—Manufacture of Carbide of Calcium. 1916.

CHAMOT, E. M.—Elementary Chemical Microscopy. 1916.

Chemical Society of London, Annual Report, vol. 13. 1916.

FALES, E. N.—Learning to Fly in the United States Army. 1917.

HERING, CARL, and GETMAN, F. H.—Standard Tables of Electrochemical Equivalents, and Their Derivatives. 1917.

HIRSCHBERG, C. A.—Compressed Air for the Metal Worker. 1917.

HUGHES, C. H.—Handbook of Ship Calculations, Construction and Operation. 1917.

KENNELLY, A. E.—Artificial Electric Lines: Their Theory, Mode of Construction, and Uses. 1917.

LOWRY, T. M.—Historical Introduction to Chemistry. 1915.

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ZSIGMONDY, RICHARD, and SPEAR, E. B.—Chemistry of Colloids. 1917.

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American Pulley Company, Getting Maximum Pulley Efficiency. Philadelphia, no date. (From the Company.)

Badenhausen Company, Catalogues, Just About Boilers, and Just About Marine Boilers. Philadelphia, 1917. (From the Company.)

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Byers, A. M., Company, Bulletin No. 30, Genuine Wrought Iron Pipe. Pittsburgh, Pa., 1917. (From the Company.)

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Carnegie Endowment for International Peace, Year Book, 1917. Washington, 1917. (From the Endowment.)

Cook, Asa S., Company, Catalogue of Wood Screw Machinery. Hartford, Conn., 1918. (From the Company.)

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Davis, G. M., Regulator Company, Catalogue 9, Valve Specialties for the Automatic Regulation of Pressure. Chicago, no date. (From the Company.)

Duplex Hanger Company, Catalogue, Edition 17, of Duplex Hangers and Caps. Cleveland, Ohio, no date. (From the Company.)

DuPont de Nemours & Company, DuPont Products Book. Wilmington, Del., 1917. (From the Company.)

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BOOK NOTICES.

THE KILN DRYING OF LUMBER, by Harry Donald Tiemann, M.E., M.F. Philadelphia and London, J. B. Lippincott Company, 1917. 316 pages, illustrations, diagrams, and tables. Cloth, 6 x 9 inches. Price, $4.

Of all structural materials in common use from time immemorial, there is none that has been applied to a greater variety of purposes or more extensively than wood, and, despite the familiarity that has been acquired with its peculiarities, there is probably no structural material whose properties cannot now be specified with a greater degree of exactness. Trees contain from 30 to 200 per cent. in water of the dry weight of the wood, and it is essential to remove the greater part of this water to make the wood serviceable. The moisture content having also an important influence upon the strength of the wood, the strength increasing with the dryness, it is highly desirable to be able to specify the moisture content of lumber within precise limits, as well as its treatment and resulting physical state.

It takes a long time for wood to become air-dry, and many woods seldom air-dry without great losses in warping, checking, case-hardening, and honeycombing. The author points out that these losses may be greatly reduced by properly kiln-drying the green material in kilns in which humidity and circulation and the temperature can be suitably controlled. The value of a technical knowledge of the kiln drying of lumber is therefore apparent, and it is the purpose of this book to present the best information available on this important subject.

The structure and properties of wood, common practices in drying, and the effects of drying are first considered. Then, passing to the main topic, the principles of kiln drying and methods of securing the necessary conditions of temperature and humidity for efficient results are analyzed in detail. Various forms of kilns in current use are described and the results obtained from them discussed at length. The work is of a very different type from that of the usual woodcraft text. The subject is presented from a consideration of fundamental principles, from which, with observations from practice, deductions are made by rational and analytical methods. While deeply interesting from a descriptive point of view, it is quite the book that will appeal to the technically trained reader who appreciates an orderly and precise method of arriving at results.

LUCIEN E. PICOLET.

PUBLICATIONS RECEIVED.

Refractory Materials: Their Manufacture and Uses, by Alfred B. Searle. 444 pages, illustrations, 8vo. Philadelphia, J. B. Lippincott Company, 1917.

Aids in the Commercial Analysis of Oils, Fats, and Their Commercial Products, a laboratory handbook, by George Fenwick Pickering. 133 pages, 8vo. Philadelphia, J. B. Lippincott Company, 1917.

Athenæum Subject Index to Periodicals, 1916, issued at the request of the Council of the Library Association. Historical, political, and economic sciences. 119 pages, quarto. London, The Athenæum, 1917. Price, 5 shillings net.

U. S. Bureau of Standards: Technologic Paper No. 95, Durability of Cement Draintile and Concrete in Alkali Soils (containing results of third year's tests), by R. J. Wig, Engineer Physicist; G. M. Williams, Assistant Engineer Physicist, and A. N. Finn, Associate Chemist, Bureau of Standards, in Coöperation with S. H. McCrory, Chief of Drainage Investigations, Department of Agriculture; E. C. Bebb, Engineer, U. S. Reclamation Service; L. R. Ferguson, Engineer, Portland Cement Association. 94 pages, plates, 8vo. Washington, Government Printing Office, 1917. Price, 35 cents.

U. S. Bureau of Mines: Bulletin 130, Blast-furnace Breakouts, Explosions, and Slips, and Methods of Prevention, by F. H. Willcox. 280 pages, illustrations, plates, 8vo. Bulletin 158, Cost Accounting for Oil Producers, by Clarence G. Smith. 123 pages, tables, 8vo. Washington, Government Printing Office, 1917.

Canada, Department of Mines, Mines Branch: Bulletin No. 16, Mineral Springs of Canada, in two parts. Part I, The Radioactivity of Some Canadian Mineral Springs, by John Satterly, M.A., D.Sc., and R. T. Elworthy, B.Sc. 60 pages, plates, map, 8vo. Ottawa, Government Printing Bureau, 1917.

United States Tariff Commission, first annual report for the fiscal year ended June 30, 1917. 26 pages, 8vo. Washington, Government Printing Office, 1917.

Concrete Highway Bridges. 27 pages, illustrations, 8vo. Concrete ships. 46 pages, illustrations, 8vo. Chicago, Portland Cement Association, 1917.

CURRENT TOPICS

The Toy Transformer and Its Hazards. C. H. THORADSON, in *Electrical Review.* (*Quarterly of the National Fire Protection Association,* vol. xi, No. 2, p. 155, October, 1917.)—Electrical transformers for stepping down 110 volts alternating current of the usual lighting circuit to much lower potential for operating electrical toys have become an established commodity. It may be said that small electrical devices used on a few volts may have no limitations as to cheapness. With the toy transformer that is connected to the 110-volt circuit it is quite otherwise, and it is of the utmost importance that toy transformers be made, as far as possible, proof against misuse.

The dangers from short-circuiting are well understood, and a number of protective devices to guard against short-circuit have been devised. The greatest danger, however, lies in the possibility of connecting the 110-volt cord to the low-voltage side of the transformer. In such a case the transformer becomes a step-up transformer, delivering a potential that can be fatal to anyone touching the secondary circuit when the current is thrown on. To determine what would really happen if a transformer is so connected, a small toy transformer that had been rated at less than 50 watts was tested with an oscillograph, showing the shape of the secondary voltage and current wave. The highest potential on the low-voltage side was in the neighborhood of 25 volts. Across the high-voltage terminals a non-inductive resistance was connected, corresponding in resistance to the body of a full-grown person. On applying 110 volts to the low-potential side, the high-voltage measured 596 volts with one-eighth ampère flowing through that resistance. The lowest secondary voltage was about three volts. When 110 volts was switched on this circuit and a corresponding resistance was connected across the high-voltage side, a potential of 1140 volts was delivered with a current of one-third of an ampère. The oscillograph showed a surge voltage superimposed on this voltage that indicated 2070 volts.

Tests of Oxacetylene Welded Joints in Steel Plates. H. F. MOORE. (*Bulletin No. 98,* Engineering Experiment Station, University of Illinois, December 10, 1917.)—A series of tests of the strength of oxacetylene welded joints in mild steel plates has been completed by the Engineering Experiment Station of the University of Illinois under the direction of H. F. Moore, Research Professor of Engineering Materials. Specimens were supplied by the Oxweld Acetylene Company of Chicago, and tests were made in the laboratories of the Station at Urbana under three conditions of loading:

(*a*) static load in tension (in a testing machine), (*b*) repeated load (bending), and (*c*) impact in tension (in a drop testing machine).

For joints made with no subsequent treatment after welding, the joint efficiency for static tension was found to be about 100 per cent. for plates one-half inch in thickness or less, and to decrease for thicker plates. For static tension tests, the efficiency of the material in the joints welded with no subsequent treatment was found to be not greater than 75 per cent. The joints were strengthened by working the metal after welding and were weakened by annealing at 800° C. For static tests and for repeated stress tests, the joint efficiency sometimes reaches 100 per cent.; the efficiency of the material in the joint is always less. This indicates the necessity of building up the weld to a thickness greater than that of the plate. The impact tests show that oxacetylene welded joints are decidedly weaker under shock than is the original material; for joints welded with no subsequent treatment, the strength under impact seems to be about half that of the material. In general, the test results tend to increase confidence in the static strength and in the strength under repeated stress of carefully made oxacetylene welded joints in mild steel plates.

Farm Reservoirs. S. FORTIER. (U. S. Department of Agriculture, *Farmers' Bulletin 828*, July, 1917.)—The main purpose of reservoirs suited to the needs of individual farmers and small groups of farmers is to store water for the irrigation of gardens, orchards, and truck farms, but they may serve also to store water for stock and to provide domestic supplies for farm dwellings. Farm reservoirs are used most commonly in conjunction with pumping plants operated by gasoline engines, windmills, or electric motors. A usual source of supply is the well, though the flow from springs, brooks, flowing wells, and small creeks is also utilized.

Water escapes from unlined earthen reservoirs in two ways other than through the outlet or wasteway. A part of the contents is absorbed by the materials forming the bottom and sides or else percolate through them, and another part is vaporized at the surface and passes off into the air. Seepage losses may be regarded as one of the most serious defects in the common practice of storing water on farms, and may be prevented almost entirely by lining the reservoir with concrete. Such a lining may cost, however, as high as 10 cents per square foot, or more than $1000 per acre-foot of water stored. Since the interest on the cost of a concrete lining might amount to more than the value of the water wasted annually, the cheaper method is often adopted of digging a trench where the centre of the embankment is to rest down to bed-rock or other good material and building therein a wall of concrete, known as a rim core wall. A clay puddle may be substituted where a concrete core wall proves too expensive. In this case a much wider trench is dug, filled with the best material available, and carefully puddled and rammed.

The customary practice in building these reservoirs is to locate them on the highest suitable ground adjacent to the pumping plant. The material for the embankments is taken from the inside, the space being first plowed and then scraped. To secure earth from the outside of the reservoir would remove the upper valuable layer of soil. Forming the banks from material taken from the inside results in lowering the bottom considerably below the natural surface of the ground and in this way lessens the effective holding capacity of the reservoir, since the water in the bottom cannot be drawn off and used in irrigation. On the other hand, there is a decided advantage in having this extra storage to stock with suitable kinds of fish.

The Quebec Bridge Centre Span in Place. ANON. (*Iron Trade Review,* vol. lxi, No. 13, p. 679, September 27, 1917.)—The work of hoisting into position the central span of the Quebec Bridge of the Transcontinental Railway over the St. Lawrence River, which was commenced September 17, was successfully concluded on September 20, when the connecting structure was bolted to the two cantilever arms. The span, 640 feet in length and weighing 5540 tons, was towed on pontoons from Sillery, where it was constructed, and was raised by eight hydraulic jacks having rams 22 inches in diameter and a working pressure of 4000 pounds to the square inch. The span was hoisted two feet at a time. The hydraulic pumps were operated by compressed air. Long mooring frames were suspended from each of the cantilevers, and huge pins were inserted into the frames at every two feet to sustain the structure until the next lift.

It will be some months before the bridge is ready for the passage of trains. The painting of the structure will occupy about three years. When complete, the bridge will shorten the railway trip between Halifax and Winnipeg by half a day. The cost of the bridge will be between $18,000,000 and $20,000,000. Its total length is 3239 feet, and the distance between the piers on which the cantilevers rest is 1800 feet. The height of the central span above the water is 150 feet. Each of the cantilever arms is 562 feet in length, and the total weight of steel, when everything is in place, will be about 65,000 tons.

The building of the bridge was commenced in 1906. The design then adopted provided for the extension of the cantilever arms until they met in the middle. In 1907 one of the arms collapsed, causing a loss of 70 lives. A new design then was adopted with a central span to be floated on pontoons and hoisted into position. The first attempt to carry out this plan resulted disastrously last year, when the hoisting apparatus broke and the span fell into the river, with a loss of 14 lives. The financial loss entailed by these catastrophes was about $8,500,000.

Phosphorescent Zinc Sulphide. E. MACDOUGALL, A. W. STEWART, and R. WRIGHT. (*Journal of the Chemical Society* (London), August, 1917, through the *Illuminating Engineer*, vol. 10, No. 9, p. 238, September, 1917.)—It seems to be recognized that zinc sulphide in the phosphorescent form can be obtained only by the action of heat. Ordinary precipitated zinc sulphide shows no sign of phosphorescence. By the application of heat, however—that is, by deflagrating a mixture of zinc and sulphur—the desired property may be produced. In carrying out this process, the temperature is of considerable importance. Below the region of 650° C. even prolonged heating produces only a poor phosphorescent effect. Between 650° and 900° the results are much better, while heating for a considerable time above 1100° again produces very poor specimens. The material produced below 650° is viscous and amorphous, that obtained between 650° and 900° semicrystalline under the microscope, and that produced at 1100° purely crystalline. It appears, therefore, that the semicrystalline state is a desirable condition to produce phosphorescence; the best samples were obtained by heating to some temperature for a time not exceeding an hour and a half. The temperature has also an effect on the nature of the after-glow. Specimens produced at 650° give blue phosphorescence, while higher temperatures lead to greens and even yellows.

The effect of impurities, such as iron, is prejudicial, even if present in minute quantity; others, such as sodium chloride, increase the phosphorescent effect. The addition of manganese, again, gives rise to a marked golden-yellow phosphorescence, and manganiferous zinc sulphide exhibits strong tribo-luminescence (*i.e.*, production of light on friction). In conformity with what appears to be the experience of other observers, the results obtained by radium stimulation do not in any way concord with those obtained by stimulation with light. One interesting fact is that the phosphorescence of a prepared sample of zinc sulphide may apparently be much diminished by washing with water. It therefore appears that some material soluble in water is necessary to good phosphorescence, and further evidence on this point is furnished by the fact that the conditions of precipitation have an important bearing on the quality of the product. It may be suggested that good phosphorescent effect is associated with the presence of a skin of zinc chloride over the sulphide, producing a condition of strain. This substance would be washed out by water and its removal might cause the diminution in phosphorescence brought about by washing.

The Status and Prospects of Gas Lighting. W. J. SERRILL. (*Transactions of the Illuminating Engineering Society*, vol. 12, No. 7, p. 292, October 10, 1917.)—A lack of uniformity in the fuel delivered to the burner is the first obstacle to good gas lighting. It does not follow that only one quality or kind of gas should be made all over the country, but rather that, when burners are once adjusted and in use, it is highly desirable that the fuel thereafter fed to them be kept uniform. In the past principally two kinds of gases have been general—coal gas and water gas—but in recent years coke-oven gas has become an important factor. These gases differ from each other in gravity, in heating power, and in air requirement, and under these conditions a desirable uniformity in the gas has not been easily maintained. The effort to maintain a standard of candlepower as the criterion of the quality of the gas, now happily in process of abandonment, has been the principal cause of variability in the other qualities. As an index of the quality, candlepower is useful only in an open-flame burner. It has no value in the incandescent gas burner; on the contrary, the effort to maintain it introduces effects that are detrimental to incandescent gas lighting, and by common consent the gas industry is abandoning the candlepower standard in favor of the heat-unit standard.

To variations in pressure are due many of the causes of dissatisfaction with gas burners. The demand for uniformity by the incandescent gas burner is not, however, completely met by the unbroken delivery of gas of uniform quality; this uniform gas must come to the burner under constant pressure. Strictly uniform pressures are possible only on high-pressure systems with a governor on each service. Pressures approaching this ideal of uniformity may be obtained on low-pressure by utilizing a system of feeder mains, or a belt line provided with governor stations located so as to feed into the distribution system at various points.

Maintaining a uniform gas at the burner is not the only benefit derived by the abandonment of the candlepower standard; an additional advantage lies in the smaller quantity of condensable hydrocarbons in the gas, with a diminution of the tendency to cause smoke by the clogging of orifices in the burners and the darkening of walls and ceilings. Second only to the objection of discolored walls and ceilings, if not indeed of equal importance, are the problems of ignition and distance control. These have to do with the factor of convenience, an attribute of prime value, and are recognized as problems of fundamental importance. Mechanical and chemical inventiveness have accomplished much toward their solution, and there is reason to believe that the end has been reached.

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THE PALATE OF CIVILIZED MAN AND ITS INFLUENCE ON AGRICULTURE.*

BY

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U. S. Department of Agriculture.

THE expression, "I do not like it," is the stone wall which blocks or hinders every attempt to introduce a new food. The purpose of the discussion this evening is to analyze the situation created by the vagaries of taste in foods and ascertain if these vagaries are not responsible for a larger part in agriculture than is commonly supposed—a controlling factor, even, in the cultivation of vast areas of land. My position in the Department of Agriculture, that of investigating the food plants of the world, to find out which could be introduced and grown in America, has perhaps permitted me to gain a bird's-eye view of the situation and warrants my making certain generalizations which grow out of twenty years of foreign and domestic correspondence and travel.

It seems to me that the present era is one of tremendous change and immense possibilities in these matters of food, and that the time is at hand when full discussion of taste in foods is opportune. The war is rapidly changing the trade routes of the world, and the Oriental tropics are brought closer to us than ever before by the lines of direct steamers through the Panama

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* Presented at a meeting of the Section of Physics and Chemistry held Thursday, October 25, 1917.

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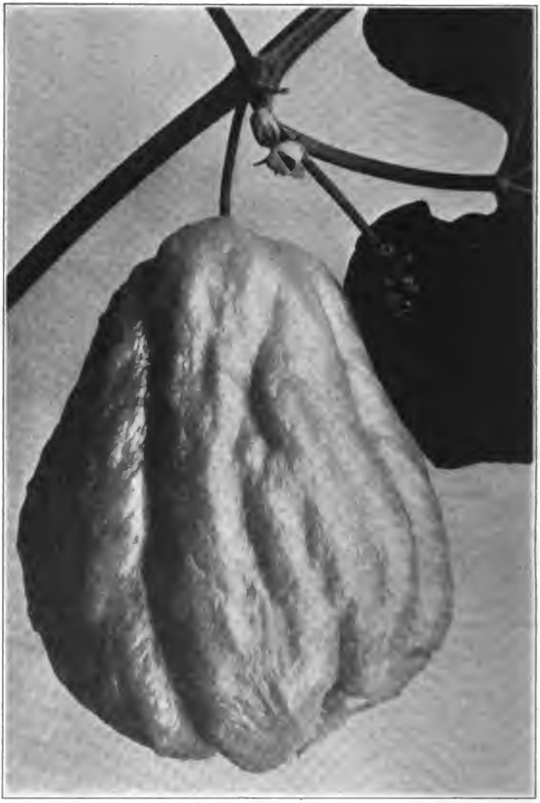


FRUIT OF THE CHAYOTE, A GUATEMALAN VEGETABLE (*Chayota edulis*). (Full size.)

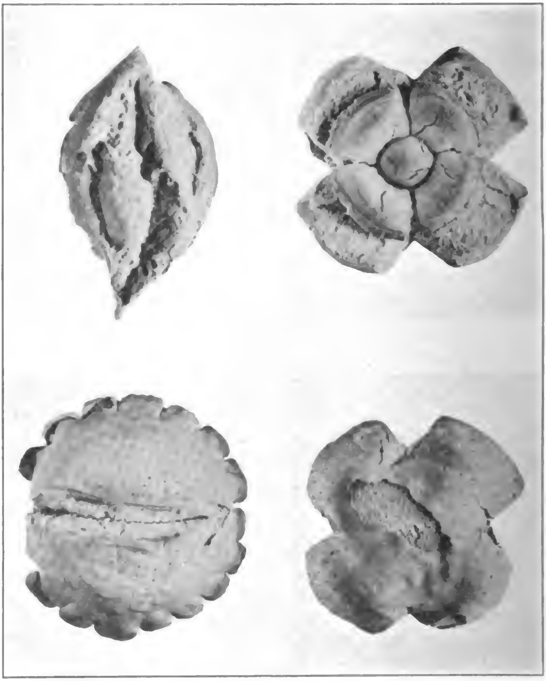
This fruit, though with no pronounced flavor, has a remarkable texture and can be used in a large variety of ways. It is more delicate than a squash or cucumber. It is a staple vegetable in those tropical countries where it is grown, and is now being cultivated in Louisiana and Florida.

Canal. New York is now in direct touch with Java and Singapore, and a new direct line to Chile and Peru has just been opened. Sanitation, the discovery of the yellow fever mosquito, the advent of good roads and automobiles, have made farm life in the tropics a very different thing from what it was a generation ago.

We have the spectacle of hundreds of millions of people studying as they never did before the food supply of the whole world with reference to their particular contribution to it as a world-problem, not, as in former years, largely as a local question. One can hear in one's imagination the food talk of the Malay rice growers as they wade knee deep in the mud of the paddy fields of the Philippines. The llama drivers on the Cordilleras of the Andes, the *beche de mer* fishers off Thursday Island, the vanilla vine growers in the Seychelles, the banana plantation darkies in Jamaica, the Chinese tea pickers on the river of the nine windings, the Labrador fishermen, the New Zealand sheep rangers, the Liberian coast boys in their oil palm forests, and the Fijian coconut growers in their atolls in the Pacific—all are more or less affected by the great war and its effect upon the price of food.

Could a Southern planter or a Western farmer have imagined that the Belgians would refuse to eat his corn or that the British would even under the pressure of war prices buy corn-meal with great reluctance, and the reason be that "corn-meal is chicken food"? The soldiers' likes and dislikes in food have no doubt restricted and hampered the prosecution of the war. Blackberry jam formed an integral part of the ration of our miniature standing army, but it is hardly to be expected that it will be available for the million men soon to be in the field. Now, while the events and facts are fresh in every one's mind, it may be well to consider whether it may not be easier to change our minds than to change our agriculture.

Consider the corn situation to-day and its bearing upon the gigantic problem before us of feeding starving Europe. When I first heard that the Belgians refused to eat corn, and that the Irish and English would eat anything else before they would touch it, my first impulse was to insist that they ought to be made to eat it. Edward Eyre Hunt, the author of "War Bread," explained and made it entirely clear to me that a shocked and outraged people, wrought up and nervous to a high degree as a result of the treatment they have received, is in no mental attitude to learn to like a new food. The task of education would have been too long and more expensive than the shifting of our own ménu at home, and in the meantime would have cost many thousands of lives. Resort was made to the use of different names



LOAVES OF SPANISH DURUM WHEAT BREAD.

In southern Spain the wheat bread is very different from ours. It is hard and yellowish and has a substance to it which ours does not have—yet the average American would not like it any better than the Spanish peasant likes our soft, spongy bread, even though it is quite as nutritious. It is made of a different species of wheat from that which we grew previous to 1898—the durum or macaroni wheat.

for corn and concealment of it in war bread with three parts of white flour. Sir Horace Plunkett informed me that unfortunately his people had grown up to look upon corn as hog and chicken food, and that this prejudice was extremely difficult to overcome, but that high prices would in time force them to eat it. One of the British commissioners to this country remarked, last spring, to one of our Southern ladies, " Madam, I wish you could send us a hundred darky cooks to teach our people how to cook corn."

The Food Administration, in its pamphlet on " Graphic Exhibits," suggests a poster explanatory of why we cannot send corn abroad. On the one side is a darky cook with apron held out to Uncle Sam, begging for ears of corn; on the other, a French baker shrugging his shoulders and saying, " I don't know how to use it."

Not to like a food which has been the staple of peoples for thousands of years and to-day is produced by the thousand million bushels and feeds hundreds of millions of people seems to us who like it a strange, incomprehensible spectacle. Yet it is no stranger than that of the American people and their indifference to that other great cereal, rice, which is produced in larger amounts than any other cereal in the world and forms the staff of life of hundreds of millions of civilized peoples.

It is said that Europe is dependent upon the wheat loaf, and the bakeries of that country are ill suited to utilize corn. We are sometimes inclined to insist that they should break away from the exclusive use of the wheat loaf and learn to make corn bread and corn cakes—yet we have not yet learned how to cook rice properly, and complain of its insipid character, which must be an attitude hard for our Oriental neighbors to understand. This indifference toward rice, of which staple we even now consume only the insignificant quantity of seven pounds per capita, has led to the abandonment of the fertile rice fields of the Carolinas, and to-day efforts are being made to find some paying crop to take its place there, because our meagre demands have been met until very recently by the California and Texas rice areas recently developed.

I find that most people whom I meet have never stopped to think whether what they eat makes any difference to any one else. They drink their cup of coffee without seeing the vast red clay hills of Brazil covered with square miles of coffee trees loaded with red berries. They do not stop to realize that their preference for coffee instead of for cocoa or tea means that their money is contributing to the great civilization of southern Brazil

A BLANCHED SHOOT OF UDO.

Unlike the asparagus or celery, the blanched shoot of udo has no objectionable fibres in it. It is crisp clear down to the ground and has a characteristic flavor the like for which, like for almost all flavors worth while, has to be acquired. The author looks forward to the season for udo as he does toward the asparagus or rhubarb season.

instead of to the tropical cacao plantation life of Venezuela or Trinidad or the beautiful hillside farm life of the tea plantations of the Orient. Whether they drink Oolong or green or black tea seems a very small difference to them, but in the aggregate it means the success or failure of vast plantations with thousands of tea pickers in China, Japan, or Ceylon.

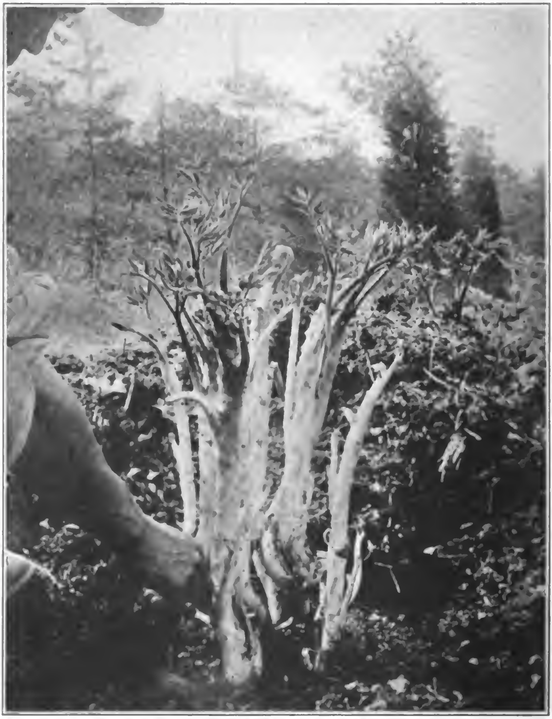
Can the fact be established that, in the past, fashion in foods, a like for a food or a positive dislike, or a mere indifference toward it has brought about the cultivation of the plant, checked or stopped its cultivation, or accelerated its widespread cultivation? If it can, there will be no longer doubt that the factor is important, and the question of its careful scientific investigation is one worthy of serious consideration by the scientific bureaus and laboratories of the country and our great educational institutions as well.

The origin of many cultivated plants dates back beyond the dawn of history, and many of them have become so almost universally grown that no traditions even are left to mark the struggle they had to gain popular favor. Others, again, are so new that they are at the present time fighting for a place on the ménu.

The wheat plant and the loaf of bread made from its kernels are universally liked. There is no race of people which does not like it. Yet it is a fact that the delicious hard bread of Spain and Russia, made from the durum wheat, a distinct species from our wheat, is not popular to-day in this country, and macaroni, the most popular form in which wheat is used in Italy, has, until recently, been little appreciated in America. These two facts hindered the development of the durum wheats when they were first introduced into this country in the nineties. If it had not been possible to export wheat to Italy for macaroni making, there is serious doubt whether we should now have had the vast fields of it in Kansas, Minnesota, and the Dakotas. Millers had to remake their mills in order to grind the harder kernels, and bakers had to learn to mix it with softer wheats.

The oat is cultivated successfully in Hokkaido, the north island of Japan, but not for human food. It is used for the purpose of feeding to cattle in that island, and is imported in the south islands for the use of military horses, whereas we devote over thirty million acres to its culture. Oatmeal is a staple breakfast dish in millions of American homes.

Buckwheat griddle cakes form the great breakfast dish in parts of New York and Pennsylvania, and are indispensable now to every city restaurant. To supply this fashion, which just after the Civil War was apparently at its height, we planted a



A HILL OF BLANCHED UDO (*Aralia cordata*).

Every spring, before the hill of udo starts into growth, it is mounded over with light soil to a height of a foot or two, or a drain tile closed with cement at one end may be substituted. Under this soil or in the darkness of the closed tile the tender shoots grow up perfectly white. They should not be allowed to become green, as this gives them a strong flavor. They are tender from top to bottom and absolutely stringless.

million and a quarter acres of buckwheat. To-day this has dwindled to three-quarters of a million. The Japanese, on their crowded areas, grew, in 1906, nearly 400,000 acres of buckwheat, yet I doubt if any Japanese who has not been in America knows the good qualities of buckwheat griddle cakes, and I am sure no New York or Pennsylvania farmer has ever tasted the buckwheat macaroni, which is the way in which the Japanese eat buckwheat. These two fashions have no relation whatever to each other, and yet each is largely responsible for the areas now under buckwheat cultivation in these two countries. They are both fashions that might die out and force buckwheat out of cultivation.

Examples could be multiplied almost indefinitely to show that just as what we like determines what we grow individually, so it does collectively.

The European grape was unsuccessful in eastern America and equally so in Japan. We originated the American grape varieties from our wild species and fortunately learned to be fond of their musky flavor before California began growing the European grape. This fondness for the Concord and Niagara and other American sorts has built up the Hammondsport grape industry along the lakes of western New York. Europeans, although they use the root of our American grape because it is resistant to the *Phylloxera* disease of their vine, scorn to eat the fruit, and there is no culture of American grapes in Europe, even though they are more resistant to disease.

The Honey Dew melon came in a few years ago and is now a rival of the grape-fruit on our tables, and grape-fruit growers fear it. There was a time when the orange growers of Riverside would have been glad if Easterners ate only navel oranges. They were not vitally interested in the exploitation of any other variety or any other fruit crop. The present production of navel oranges in California approximates 27,000 carloads a year, or about two-thirds of the total orange shipments of the state. Yet one of the principal growers of Riverside has just reported to me that the recent hot wave almost completely ruined the navel orange crop this year, and he wants to grow something else. The fixed fashion of eating oranges and grape-fruit makes people keep on buying them regardless of cost, though the freeze last year cut the Florida crop to a quarter of normal and the drouth cut the California navels out entirely.

How did seaweeds and candied grasshoppers come into use in Japan, and fried rhinoceros hide in Africa, and powdered deer horns in China, and pickled pigs' feet in Germany, and mouldy cheese with skippers in it in England, and snails and frogs' legs in France, and grasshoppers, fried and reduced to a meal, in Arabia, and snakes and lizards among the North American Indians, and the octopus among the Neapolitans, and wood-grubs among the New Zealand Maoris, and larks' tongues and eels fed on the flesh of slaves in Rome, and caviar, the eggs of the Volga sturgeon, among the Russians, and rats and mice and dogs and cats by the Chinese, and human flesh by the Fiji Islanders? Is it reasonable to suppose that these customs were acquired in some mysterious evolutionary way? Is it not highly probable that these foods came into vogue just as we know coffee and tea and the potato and tobacco and chocolate have come to be fashionable to-day in European and American countries, through the encouragement given those who set the fashions of the day?

THE "DOVE-KILLER" SOY BEAN.

Some kinds of soy beans, such as the "Dove-killer," are delicious when gathered green, boiled in their pods in salted water, and then shelled. As shown by Mr. Morse, of the Department of Agriculture, they are quite as attractive as lima beans and are even more delicate in flavor, and, as the vines require no poles to grow on, they are easier of cultivation than the lima bean.

Imagine the return of Raleigh to Great Britain and the social prestige which he must have had as the great explorer of the New World! Is it any wonder that men and, later, women, too, have followed him in the smoking habit which he brought back with him? Consider the millions of acres devoted to tobacco to-day as a result of the smoking fashion.

The rise in favor of the potato is one of the most spectacular in the history of the introduction of new food plants. Sir Walter Raleigh is given credit for its introduction into Ireland. The friars of Spain took it to Italy. There are records of the governor of Mons having received it from the papal legate of Belgium. When we remember the rank of Raleigh and the standing of the Catholic Church, it is easy to understand how potato eating became fashionable in Ireland—came to be the great food crop of that island. It was, in my opinion, the fashion for it which started its cultivation.

Columbus, on his return to Spain, presented a sweet potato to Queen Isabella, and to-day it is an important root crop in Spain and one of the principal food plants of the Madeira Islanders. The Portuguese seamen took it to Japan in those days when they were the great and powerful foreigners in the eyes of the Japanese. To-day the sweet potato forms one of the principal crops grown on the upland fields of southwestern Japan, and is a most important food of the poorer classes.

The account given by the Japanese of the introduction of tea into Japan is a striking picture of the influence of a fashion upon a great plant industry. It was cultivated by the Chinese previous even to 2700 B.C., and had become fashionable there long before the Japanese introduced it into their ménu in 805 A.D. The Director of Agriculture of Japan, in his "Outlines of Agriculture," remarks that "at the beginning the Imperial court patronized and encouraged its cultivation, but later on the people at large began to appreciate it, so that it soon became an article of necessity for the people of all ranks and conditions in Japan. Therefore the cultivation of the tea plant has been extensively carried on in all quarters of the country, and the patronage given by the people in the upper class of society caused a striking improvement in the art of tea manufacture."

When we consider that the peach, the orange, the jujube, and at least one type of cherry and edible hawthorn originated in China, it is difficult to understand why fruits have not become more popular in Japan. The Director of Agriculture on this point is clear, for he says: "The Japanese have no custom of eating fruits as dessert, so that the demand for fruits was comparatively limited; . . . but with the frequency of communications with European countries changes have been wrought in customs and usages of the people which have strikingly augmented the demand for fruits."

Compare this statement with the last report of our own Secretary of Agriculture: "It is a well-known fact that the consumption of fruits and vegetables has increased considerably in recent years, and that they constitute a larger and more important part of the permanent diet of the people."

TWO DASHEEN CORMS AND THEIR TUBERS.

These are the product of a single hill of dasheens. The tubers are easily broken off of the corms and can then be cooked and treated just as potatoes are. They contain more protein and starch per pound than the potato, and consequently require more butter or gravy. They have a delicious nutty flavor.

I cannot avoid the feeling that these two officials, speaking of their own people as a whole, are a good deal like two mothers speaking of the peculiarities of their own families. "Well, my family won't eat that," is a familiar expression which one hears everywhere.

Did you ever watch an amœba, that primitive naked drop of protoplasm, send out one of its long feelers or pseudopodia toward a bit of copper or other substance, and, as soon as it comes within the radius of the chemical activity, recoil and return to its rounded shape? Taste in its primitive form is there, and on up through all animals, before the birth of the great organ of intelligence, and even after, it is a guiding factor of existence. If the squash bug would only change its taste and be satisfied with the pigweed, or the cabbage butterfly larva with the pokeweed, or the codling moth with our wild cherry instead of the apple, or the dog become a vegetarian and leave the sheep alone, or the horse, like the goat, live on bark and twigs, or the cow refuse to eat garlic, or hawks and foxes confine their taste to owls and muskrats instead of molesting our chickens, or even if grasshoppers were not such omnivorous feeders and ate only grass instead of every living green thing, the world we live in would be different. But we cannot change these inherited tastes, though they even are being modified somewhat to meet the new conditions arising on the planet. There are conclusive proofs, for example, that cats and rabbits wandering through our gardens taste of the new plants which are put there. The cats of Boston learned in less than two years from the time of its introduction into America that a wild vine from central China was good to eat, and ate it to the ground. The wild rabbits of western Canada singled out, nibbled, and killed a new species of ash from Turkestan the first year it was grown in a nursery on the prairie.

The appearance of intelligent man in the world, however, creates a new situation, and it is a question whether instinctive taste has not already disappeared in him, although perhaps some of the vagaries of taste in foods which are hard to explain do come down as instinctive traces from our ancestors.

Taste is the avenue of our contact with the world of chemical things. It is, after all, one of our five senses. Is it not worthy of all the study which can be given to it, and should not the education of the human palate become a matter of great importance and every effort be made to teach the value of a wide liking for everything that is good to eat? Let us not be misled by those who scoff at the problem. Scoffing is a trait unworthy of intelligent man. Think of the conservatories of music where the sense of hearing of thousands of our youth is trained, and the academies of art where the sense of sight is cultivated, and then compare these with the schools of Domestic Economy and see what a gulf there is between them. How far we must yet go to put the cultivation of the American palate where it really belongs!

The question, it seems to me, may with perfect propriety be asked in regard to our children, Are they not already acquiring incurable habits in foods? How many housewives stop to realize how the taste for sugar has grown in this country, or that, whereas France must limit each citizen to twelve pounds per year, we are said to be eating in the neighborhood of ninety. There was a time in the Middle Ages—and that is, after all, not many generations ago—when the only sweet things man had were honey, raisins, and such things as sweet fruits. Sugars were unknown and probably not liked by hosts of our ancestors—there are some to-day who do not care for sweets; but the sugar habit, like the tobacco habit or the chewing-gum habit or the alcohol habit, is going to bring about acute suffering in those who must give it up or curtail it, just as the bread habit and the meat habit are hard to change.

A FIELD OF DASHEENS IN FLORIDA (*Colocasia esculenta*).

The dasheen plant looks like the "elephant ear" of our gardens. It grows on soil which is too moist for the potato, and its tubers mature in November in the South, when potatoes are being shipped in from the North. When this vegetable becomes widely known, hundreds of thousands of acres of land not now utilized profitably will probably be planted to it.

We have a curious spectacle in our common schools—thousands of little children poring over books on the volcanoes of the world which they will never see, the North Pole, which they can never expect to visit, and, when the noon hour comes, satisfying their hunger from their dinner pails with no word from the teacher regarding perhaps the most acute sense they have—the sense of taste.

I left school and college with about as untrained a palate as I had when I started in, and it took the knocks of travel to demonstrate to me the desirability, the necessity at times, of learning to like everything which is fit to eat.

The researches of modern chemistry have revealed startling things with regard to the requirements of our bodies—things which cannot fail to make one feel that discoveries of gigantic importance may at any time be made. To learn that rats or pigs will starve to death on an exclusive diet of Indian corn; that the rice we have all been eating will, if taken alone, produce the starvation disease known as beri beri; that a few cubic centimetres of the white of egg, if injected into the blood, so sensitizes the protoplasm of our bodies that a second dose will kill us almost as quickly as a dose of snake venom, are facts which make us wonder what discoveries we are approaching.

The consideration of food as fuel was a great step in advance in the food question, but the discovery of McCollum, that certain substances contained in butter fat and the green leaves of plants are just as essential for a complete food as the proteins, fats, carbohydrates, and mineral constituents contained in grains, has opened a new door of possibility. The machinery for determining the comparative protoplasma building and conserving value of foods is rapidly being created, and it is curious to reflect that the despised rat is being made one of the chief tools by means of which the food chemist is working them out. The human calorimeter, which amused the public at first, has come into prominence as one of the great tools of this generation. We are in a position such as we have never occupied before to test the value of the food plants of the world.

All these converging changes, it seems to me, indicate the present as a remarkable opportunity in which to consider whether the stone wall of taste is really a stone wall, or whether it is something which the reason of man can tear down—whether, in other words, the time has not arrived when we should cease insisting that our likes and dislikes in foods are nobody's business anyhow, and begin to realize in how far this caprice of fashion will hinder the development of the agriculture of the future.

"*De gustibus non disputandum*" is an expression which was originated by the scholastics of the Middle Ages and has, curiously enough, blocked for centuries the discussion of one of the most important subjects connected with the development of the human race.

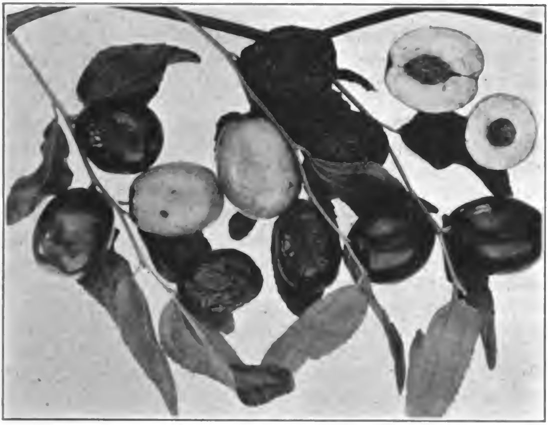
The fact that plants can be found which are suited to different soils and climates, easier than the soils and climates can be changed, has been conclusively demonstrated. The date palm is perfectly at home in the Imperial Valley where the apple is a dead failure. The dasheen is a success on soils too wet for the potato. The kafir sorghums live and bear heavily on lands too dry for corn. Wheat cannot be grown everywhere, potatoes are a success only in certain regions on certain soils, and there are enough types of soil and climate to make places for more crops than most people know exist in the whole world.

FACTORY FOR PRODUCTION OF SOY BEAN PRODUCTS.

The Japanese and Chinese do not eat soy beans as we do the navy beans. They make curds and cheeses and the remarkable soy sauce out of them. This soy sauce takes the place of meat gravy in the diet of hundreds of millions of people, and is worthy of the serious consideration of Americans. It is consumed in immense quantities by all these people. The *per capita* consumption reaches ten quarts a year in Japan. It is about as strong in flavoring power as beef extract. The taste for soy sauce in America is growing, and is being stimulated by the Chinese restaurants of the country.

The spread of plant diseases and the cost of their control is another factor forcing man to change his crops. Already in certain plant industries they are taking all the profits out of the cultivation of those plants. As the plantations of one crop grow in size and are owned by larger numbers of individuals, these costs of control often increase, and our farmers should be able to shift to other crops less liable to disease.

The pear blight has wiped out great orchard areas in this country, and other crops have taken their place; the watermelon disease has made watermelon growing unprofitable in certain sections; the glume rust of wheat threatens serious injury to the wheat area of the Northwest; the nematodes of Southern soils make fig growing in many places there impossible; the new peach twig borer may be the last straw that will discourage peach growing wherever it spreads; the American chestnut has already practically gone, and we will be dependent probably upon some immune hybrid between the Japanese chestnut and the chinquapin for our Thanksgiving chestnuts.



FRUITING BRANCH OF THE CHINESE JUJUBE (*Ziziphus sativa*).

The Chinese large-fruited jujube constitutes a new fruit tree for America. It is adapted to the hottest regions of the Southwest, where it fruits abundantly. The fruits shrivel on the tree and can be gathered and kept in a dry state, to be processed with sugar later or used like raisins in puddings. The processed jujube is not inferior to the Persian date in flavor. This is the Mu shing hong variety (S. P. I. No. 22684).

Armsby has emphasized the limitations of the hog and the steer as producers of necessary food material when fed on human food grains. Lusk points out the fact that indulgence in meat is due primarily to desire for strong flavor, and these facts may make meat too expensive for some of us and drive us to the use of soy sauce, the great flavoring extract of the Orientals. These peoples have not acquired the expensive taste for beef; in the place of beef gravies they consume over ten quarts per adult per year of a sauce made from soy beans and wheat—a teaspoonful or so at a meal. That changes in our ménus are coming there can be no doubt. The above causes are at work, and some of the changes that we may have to adjust ourselves to in the next generation may be surprising.

Conservatism in taste has no doubt been a great stabilizer, but has it not increased the chances for speculation and made "corners" possible? It has enabled the farmer to know with some degree of certainty when he plants his orchard that there will be a demand for the product of his orchard ten years hence. Doubt as to the existence of this demand will prevent him from planting the orchard. It has simplified, no doubt, some of the marketing problems which depend upon advertising. The change of fashions in foods adds one more element to the gamble of agriculture. A broad universal diet, however, should give room for the development of all the good plant and animal foods of the world. Our American children of the next generation should be more untrammelled than we have been in their diet, and able at any time to shift from one food product to another as the price or shortage dictates. They should have a mobility of action which will enable them to go anywhere and eat anything fit to eat, and test out and eliminate or keep, as the case may be, any new foods which the investigations and experiments of plant introduction and plant breeding and the growing genius of food chemistry will surely bring into existence.

But throughout all this discussion I cannot help wishing that the great man Franklin, the greatest in some ways that America has produced, could look up from his bowl of porridge, which he says in his autobiography formed for years his daily breakfast, and tell us how this great country can be utilized agriculturally, if everybody should insist on a breakfast of oatmeal porridge and milk and nothing more.

PROPULSION OF SHIPS.*

BY

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It is doubtful if any branch of engineering has advanced as slowly and cautiously as that branch of marine engineering which has to do with the propelling of machinery. Reliability seems to have been the only thing in view, and economy seems, until very lately, to have received very little consideration.

As an illustration of this point, I would mention that some of the Hudson River boats still have side wheels and use boilers with about 30 pounds steam pressure, producing a brake horsepower with about 30 or 40 pounds of steam.

Steam engines were built as early as 1765, but it was not until 1807 that one was used to propel a boat. Electricity was used for power transmission as long ago as 1876, but its application as a medium for transmitting power to the propeller of a ship did not take place until 1908. This all goes to show that progress in marine propulsion is very slow, the tendency being to follow the old and beaten paths.

Until within the last few years, reciprocating engines were used exclusively for the propulsion of boats, but with the advent of the steam turbine and its almost universal use on shore, where, due to its high steam economy, small size, and light weight, it has practically superseded the reciprocating engine, the practicability of its use for the propulsion of ships began to be considered. It is largely due to the untiring efforts of Sir Charles Parsons that turbines are now rapidly replacing reciprocating engines for the propulsion of ships. It may not be out of the scope of this paper to give some of the reasons why the turbine is preferable to the reciprocating engine as a prime mover.

First: Because it gives simple rotation and admits the possibility of a large range of expansion. At present the best steam engines of the triple- and quadruple-expansion type cannot, on account of the size of the low-pressure cylinder, be made with an expansion ratio of more than 16 to 1 or 20 to 1. In the turbines, however, there are practically unlimited possibilities of expansion, depending almost entirely upon the temperature of the condensing water. A vacuum of 29 inches is not at all an unusual occurrence, and 29.5 inches is being recorded in some of the larger central stations during the winter months. What this means may be better understood when we consider the available energy of a pound of steam when it is expanded from boiler pressure to various degrees of vacuum.

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* Presented at a joint meeting of the Electrical Section of the Institute and the Philadelphia Section, American Institute of Electrical Engineers, held Thursday, October 11, 1917.

200 pounds pressure to 24 inches vacuum....	220,000 foot-pounds
200 pounds pressure to 26 inches vacuum....	238,000 foot-pounds
200 pounds pressure to 28 inches vacuum....	265,000 foot-pounds
200 pounds pressure to 29 inches vacuum....	289,000 foot-pounds

In other words, a turbine can realize about 25 per cent. more of the energy of the steam than the reciprocating engine, which means a saving of 25 per cent. in fuel, size of boilers, etc.

The small size of the turbines is, of course, another very important item. Incidentally there are a great many minor advantages, such as saving of oil, attendance, ash handling facilities, etc.

When the turbine is considered for ship propulsion there are a few facts that must be borne in mind, namely:

High-speed turbines are lighter, cheaper, simpler, and more economical than the slow-speed turbine. Propellers, on the other hand, are, within well-known limits, confined to slow speeds for high efficeincy. Turbines, therefore, when used for direct connection to the propeller shaft, must necessarily be designed to operate at a speed which is too low for the economical use of steam, and even then cannot be conveniently designed for a speed low enough to secure efficient propeller action. Parsons realized this and advocated the use of direct-connected turbines only for high-speed ocean liners requiring a large amount of power, and the *Mauretania* is probably one of the best examples of ships using this method of propulsion. The horsepower of the *Mauretania* is 68,000, the speed about 26 knots, and about 43.5 tons of coal per hour is required. The water rate obtained is about 11.5 or 12 pounds and the coal consumption about 1.5 pounds per shaft horsepower-hour.

A few years later, when the White Star Line decided to build the *Olympic* and the *Titanic,* which were slow-speed ships requiring about 45,000 horsepower, Mr. Parsons advocated a combination of two reciprocating engines exhausting into a low-pressure turbine, which gave him an economy about comparable with the *Mauretania.*

As you doubtless all know, the steam engine is a very efficient prime mover when operating in the higher temperature ranges; that is, an engine may have as high as 80 per cent. thermodynamic efficiency when operating from boiler pressure to atmosphere, whereas if it was operated down to a 28-inch vacuum the efficiency would not be greater than 40 or 50 per cent. On the other hand, the turbine works efficiently in the low-pressure end of the cycle, so that by using a reciprocating engine in the upper ranges in combination with a turbine to utilize the energy in the low-pressure ranges an overall efficiency is obtained which may be above that obtainable with either the reciprocating engine or the turbine when working alone. In the *Olympic,* all reversing and manœuvring is done with the reciprocating engines, making it possible to build a simple and efficient low-pressure turbine.

It is therefore necessary, in order to obtain the advantages of the high-speed turbine and at the same time to be able to use a low-speed efficient propeller, to have some form of reduction gear between the propeller and the prime mover. This condition is what led up to the application of electricity to the propulsion of ships, to the mechanical reduction gear, and also to speed reduction by means of hydraulic transmission. Electric propulsion is best suited to very large, high-powered vessels, especially in cases where good economy is desired at two or more speeds, as in the case of warships. The reasons for this are as follows:

Electric transmission affords a very simple and practical means of speed reduction in almost any ratio which may be desired.

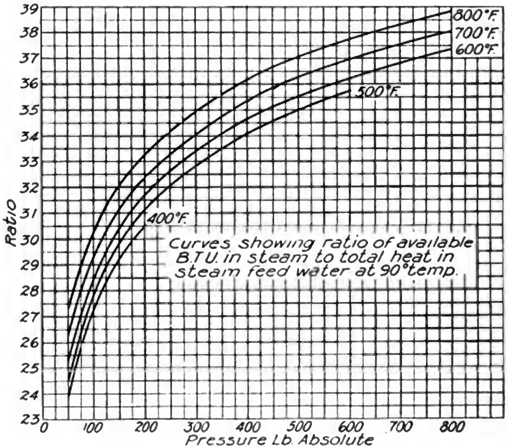
It affords a very simple means of reversal by a change of electrical connections without mechanical devices, complication of piping, valves, etc. Any desired reversing torque can be obtained without affecting the efficiency of the equipment in the forward direction.

In the case of battleships, the feature that is particularly important is that electric transmission affords means by which the ratio of speed reduction is changeable by simple electrical connections, thus making possible the economical use of the same apparatus, both under high-speed and cruising conditions.

Electric transmission makes it possible to use a plurality of cruising and generating units, so that damage to one or more parts will not disable the vessel.

With electric transmission, high steam pressure and superheat can safely be used, and the gain in fuel economy by its use is best shown by these curves. A steam temperature of 700° is now successfully used in Europe, which with 500 pounds steam pressure would give a superheat of 233°. Heat available for work would then be about 36.3 per cent., whereas under ordinary steam conditions, say 200 pounds pressure and 50° superheat, we have only 30.75 per cent. available, a net gain of 18 per cent. in fuel, which would more than compensate for any additional weight or cost of the electrical equipment.

FIG. 1.



Turbo-generators are now built with an efficiency of over 80 per cent., which with motors of 95 per cent. efficiency and a boiler efficiency of 80 per cent. would produce a shaft horsepower-hour with 0.825 pound of coal (containing 14,000 British thermal units per pound) or 0.61 pound of oil (19,000 British thermal units per pound), the latter figure comparing favorably with Diesel engines when lubricating oil is taken into consideration.

The first electrically propelled boats in this country (outside of electric launches) were two fireboats in the city of Chicago, the *Joseph Medill* and the *Graeme Stewart,* which were equipped with electric propelling machinery in 1908. Their equipment consists of two Curtis turbo-generating units of 1000 horsepower capacity each. Each turbine is connected to a 250-kilowatt, direct-current generator and a 1000-horsepower centrifugal pump. There are two propellers, each driven by a 250-horsepower, direct-current, 220-volt motor. The equipment is arranged for pilot-house control. The wonderful manœuvring qualities, simplicity of control, and fine economy of these boats, together with the fact that up to the present time no money has been spent for repairs to the electric propelling machinery, make the vessels the most efficient fireboats in the country and probably in the world. In the case of these fireboats, direct-current apparatus, with its complication of brushes and commutators, was used, but for larger installations alternating current is used, which greatly simplifies the apparatus.

The second example of electric propulsion is the large United States collier *Jupiter.* Due to the wonderfully fine performance of this collier, which has now been in service for about four years, the Navy Department decided to install electric propelling machinery in the battleship *New Mexico,* which is now nearly completed at the New York Navy Yard, and the apparatus for which has recently passed all government tests at the Schenectady Works of the General Electric Company. The Navy Department has also decided to install electric propelling machinery in six other new battleships requiring about 33,000 horsepower each, and in five large battle cruisers requiring about 180,000 horsepower each.

Mr. W. L. R. Emmet, to whom all credit is due for the introduction of electric drive in vessels in this country, read a paper before this Institute, about four years ago, describing quite fully the *Jupiter* equipment as being built, and predicted results in regard to economy which have more than been borne out in actual service. A short description of the *Jupiter* will be given.

The *Jupiter* is a sister ship of the *Cyclops* and the *Neptune*. They each have 20,000 tons displacement and a carrying capacity of about 12,000 tons of cargo. The principal dimensions are: Length, 548 feet; breadth, 65 feet; depth, 39¼ feet; draught, 27 feet 6 inches. The *Cyclops* is equipped with reciprocating engines and the *Neptune* with Parsons geared turbines (built by the Westinghouse Company).

In giving the General Electric Company the contract for the *Jupiter* equipment, a water rate of 13 pounds per shaft horsepower at 14 knots and 15 pounds per shaft horsepower at 10 knots was guaranteed. It was also provided that in case of failure of the electrical equipment it should be removed without expense to the government, so that reciprocating engines which were originally contemplated for this vessel could be installed in its place. This feature limited the design somewhat, for, while it was believed by its designers that electric propulsion would show a great advantage over any other system, even greater improvement could have been accomplished if the vessel had been designed with a view to obtaining all the advantages incident to electric drive.

During her official trials the *Jupiter* maintained an average speed of 15 knots for 48 hours, with 7152 horsepower delivered to the propeller shafts and a propeller speed of 116.72 revolutions per minute. The water rate as actually measured was 11.68 pounds per shaft horsepower-hour. Due to the fact that the steam pipe between the boiler and turbine was too small, the steam pressure at the turbine was only 168 pounds instead of 190 pounds, for which the machine was designed. Since the official trials took place a larger steam pipe has been installed and the water rate reduced to 11 pounds.

During her 10-knot run the water rate was 12.31 pounds. It will be seen from this that the guaranteed water rates of 13 and 15 pounds were beaten by about 20 per cent. The *Jupiter* is to-day, according to the government records, making a speed of 12 knots with a coal consumption of only 55 tons a day, which is a record about 35 per cent. better than any boat of her size afloat to-day. The *Cyclops* on her trials developed 14.6 knots with about 6000 horsepower and a steam consumption of about 14 pounds, or about 25 per cent. greater than the *Jupiter*.

The *Neptune*, equipped with Parsons geared turbines, has just recently had her trials and the published results give us the following comparison with the *Jupiter* and *Cyclops:*

	U. S. Naval Colliers		
	Cyclops	*Neptune*	*Jupiter*
Weight of propelling machinery only, tons......	280	150	156
Steam consumption at maximum speed, pounds per shaft horsepower-hour	14.0	13.4	11.1

The equipment of the Jupiter consists of one turbo-generating unit with an induction motor coupled to each of the two propeller shafts. The generator is of the 3-phase type designed for a normal output of 5000 kilowatt at 2300 volts. At a speed of 14 knots the turbine runs at about 2000 revolutions per minute and the motors at 110 revolutions per minute. The generator has two poles and the motors 36 poles, making a speed reduction of 18 to 1.

The speed of the ship is controlled by a governor which was specially designed for a very wide range of speed adjustment. It operates from the maximum speed down to a speed of four or five knots per hour. The speed can also be controlled independently from the main throttle valve, which is also designed so that in case of excess speed it is closed automatically by the emergency governor, which operates independently from the main governor and is set to close at a speed slightly higher than the maximum speed of the boat.

The motors are of the 3-phase induction type and have 36 poles. The windings are made waterproof. The rotor windings of the motors are connected to collector rings, which under normal conditions are short-circuited by a slider on the shaft. These collector rings are connected by means of brushes to water-cooled resistances, which are provided for the purpose of obtaining a high torque in starting or reversing. In this particular case they are designed to give more than full-load torque. When the motors are running with this resistance in the circuit the current flowing to the motors is always limited so that all the manœuvring can be done by simply opening and closing the ahead and reversing switches.

When running with the resistance in, the *Jupiter* will reach a speed of about 10 knots. These resistances afford a very quick and powerful reversal, but the ship can be operated without them, and is, as a matter of fact, a great deal of the time. In this case, reversing is accomplished by slowing down the generating unit, which also slows down the propellers, the reverse connections are made, and the turbine again brought up to speed, which will bring the motors up to speed in the reverse direction.

The switchboard equipment is very simple. It consists of one ahead and one reversing switch for each motor, a field switch for the generator, ammeter, voltmeter, wattmeters, and frequency meters graduated in revolutions per minute. The switchboard has also integrating wattmeters which record on a dial the total amount of power going to each motor and makes a very interesting record for each trip of the boat.

The excitation of the generator is obtained from the lighting circuit of the ship, which consists of three small turbine-driven, direct-current generating sets. One of these sets is more than sufficient to furnish the necessary excitation.

The third instance of electric propulsion is the new U. S. battleship *New Mexico,* which is now under construction at the New York Navy Yard. This installation provides conditions where the advantages of electric propulsion can be realized. The *New Mexico* is the largest and most powerful battleship which has been laid down by our navy up to the present time. She will have a displacement of 32,000 tons and a designed speed of 21 knots, requiring about 28,000 horsepower. The propelling machinery is, however, designed to deliver a maximum of 37,000 horsepower, and it is believed that this will give her a speed of 22 knots.

The equipment will consist of two turbo-generating units, four propelling motors (one for each shaft), switching apparatus, cables, instruments, etc. The contract also calls for two 300-kilowatt non-condensing, direct-current turbo-generators, which will furnish excitation and power to drive the auxiliary machinery. As the General Electric Company was required to guarantee the steam consumption of the propelling machinery, including the auxiliaries, the greatest care was taken in their selection, and they are all to be electrically driven. The exhaust steam from the direct-current generating sets which operate non-condensing will be used for heating the feed water, and any that may not be required for this purpose will be exhausted into the main turbine. The generators for the *New Mexico* are bi-polar alternators, and the motors are arranged to be connected for either 24 or 36 poles. For economic cruising at a speed of 15 knots or less, only one generating unit will be required with the motors on the 36-pole connection. For higher speeds the 24-pole motor connection will be used with both generators. One generator, however, will be capable of driving the boat up to a speed of about 19 knots.

Speed variations with either motor connection will be obtained by varying the generator speed, and a governor will be installed similar to that used with the *Jupiter* equipment.

The steam consumption guarantees as made to the government cover the total amount of steam used both by the main generating units and the auxiliaries, and are as follows:

Steam Pressure 250 Pounds Gauge at Throttle.

10 knots	14.6 pounds per shaft horsepower-hour
15 knots	11.4 pounds per shaft horsepower-hour
19 knots	11.1 pounds per shaft horsepower-hour
Max. speed	11.9 pounds per shaft horsepower-hour

Very heavy penalties are attached to these guarantees in case they are not met, namely, $25,000 per pound for the two lower speeds and $20,000 per pound for the two higher speeds.

At full speed the *New Mexico's* propellers will operate at 175 revolutions per minute, the lowest speed permissible within the space allowed. The propeller speed for the sister ship of the *New Mexico* with Parsons type turbines is 240 revolutions per minute, which, according to Captain Dyson, would indicate a propeller efficiency 9 per cent. worse than is expected on the *New Mexico,* and this difference would more than compensate for the electrical losses in the motors and generators.

In order to be able to correctly judge the relative economy of different methods of propulsion, it may be interesting to compare the water rate per effective horsepower, taking for examples of such different methods the battleships *Florida* and *Utah,* which are equipped with Parsons turbines; the *Delaware,* which has reciprocating engines, and the *New Mexico,* with electric drive.

	Propeller Speed	Water rate per effective horsepower per hour.		
		12 knots	19 knots	21 knots
Florida	328	31.8	24.0	23.0
Utah	323	28.7	20.3	21.0
Delaware	122	22.0	18.7	21.0
New Mexico	175	17.3	15.0	16.4

The guaranteed weight of the propelling machinery for the *New Mexico* without the auxiliaries is 530 tons, with a penalty of \$500 per ton for any excess over this amount. The estimated weight of the Parsons turbine equipment for this vessel was 653 tons.

The contract price for the *New Mexico* machinery was \$431,000, and the Navy Yard estimates show that a saving of \$200,000 will be effected by using this equipment instead of the Parsons equipment as originally contemplated.

ELECTRIC PROPULSION FOR LARGE BATTLE CRUISERS.

These vessels are designed to have a speed of 35 knots, at which speed they will require about 180,000 horsepower. There are four propellers operating at 250 revolutions per minute at maximum speed.

The installation proposed for these ships consists of four high-speed turbo-generators, each having a capacity of about 35,000 kilowatts. On each propeller shaft there will be two independent induction motors, each having a capacity of 22,500 horsepower. The switchboard will be provided with an arrangement by which any combination of generating units and motors can be used, and starting, stopping, and reversing can be instantly done by movement of a lever. All changes of connections are made on dead circuits, so that there can never be any big rushes of current to strain the apparatus. Safety devices are also provided so that any unbalancing of current will open the circuit of that particular unit in which it occurs.

The total weight of the complete equipment for one of these vessels is about 1800 tons, of which the turbines alone weight about 350 tons.

That electric propulsion can also be profitably applied to a small boat is proved by Mr. Ljungstrom, in Sweden, in the case of the small coastwise steamer *Mjolner,* which is only 225 feet long, 56 feet beam, and 15 feet draught, requiring 900 horsepower. Stockholm's Rederiaktiebolajet Svea decided to build two sister ships, the *Mimer* and the *Mjolner.* The *Mimer* was equipped with triple-expansion engines, and Mr. Ljungstrom guaranteed a saving of 30 per cent. in fuel with his method of electric propulsion in the *Mjolner* over the *Mimer* equipped with engines. The boats have now been built and tested, and the electrically propelled boat showed a saving of 42.3 per cent. in fuel consumption. This is indeed a remarkable record, but may be partly explained by the increased efficiency of the boiler plant. For his electric drive Ljungstrom uses 218 pounds steam pressure and 235° superheat, and this alone would effect a saving in coal over the *Mimer* of about 15 per cent.

In this boat Ljungstrom uses two 400-kilowatt turbines running at 7200 revolutions per minute, generating 3-phase, 120-cycle current at 500 volts. This current is used to drive two induction motors which are geared to the main propeller shaft. The motors run at 900 revolutions per minute and the propeller shaft at 90 revolutions per minute. All of the auxiliaries are electrically driven, which affords another appreciable saving.

Mr. Ljungstrom has done some wonderfully fine engineering in connection with this equipment and has combined electric propulsion with mechanical gearing, which is a great step forward.

The greatest competitor of electric drive at the present time is the high-speed helical gearing which is now coming into such universal use. This method of drive has, however, certain limitations as compared with electric drive, some of which I will endeavor to mention. The manœuvring qualities cannot be made equally as good as with electric drive. Noise is, of course, practically eliminated with electric drive, whereas with gearing there must be some noise. There are also certain mechanical limitations to the use of gears which do not exist with electric drive. Briefly stated they are as follows:

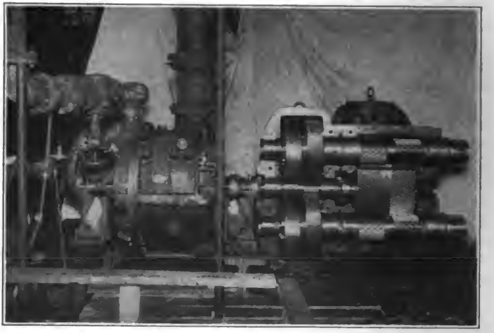
The stresses on the tooth surfaces increase with the diminution in the number of teeth in the pinion, making it difficult to use very small pinions in order to secure large ratios of speed reduction. The length of the pinion and the output for a given diameter is limited, due to the torsional elasticity of the metal, which prevents equal distribution of load over the whole surface. As the gears become large and long, springing of the hull of the ship in a heavy seaway tends to throw very heavy strains on the teeth.

For installations where a large amount of power is required, multiplications of pinions becomes necessary, which means dividing up the turbine element into smaller units. This, of course, tends to decrease the efficiency, increase the weight, and produce a much more complicated outfit. In cases where large powers are required with slow-speed propellers, the gears become very large and expansion strains due to heat may introduce great errors in the surface engagement of the gears which would throw prohibitive strains on the teeth.

With gear drive, reversing turbines are always necessary, and they introduce considerable loss, as they are always running in the reverse direction when the ship is going ahead. The losses due to this turbine friction amount to about 1½ to 2 per cent.

At the present time, for vessels requiring up to about 12,000 horsepower, or 6000 horsepower on each propeller shaft, mechanical gearing is lighter, cheaper, and more efficient than electric drive. For destroyers or light scout cruisers, where saving of weight is of the utmost importance, the high-speed geared turbine has no competitor.

FIG. 2.

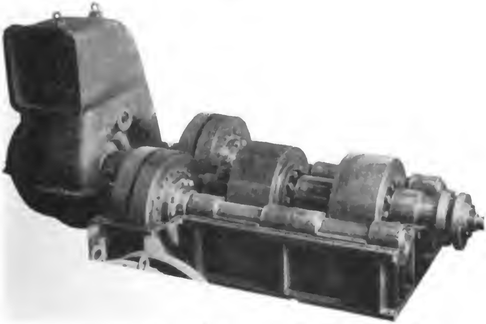


1750-horsepower turbine and 3200/137 R. P. M. reduction gear for U. S. S. *Nevada*.

About five years ago the General Electric Company began experimenting with flexible gears of the Alquist type, and results obtained showed that with this type of gear heavier loads could be carried than with solid gears, also that the noise was very materially reduced. The Alquist flexible gears are built up from disks suitably formed so as to facilitate axial deflection. On account of helical angle there is a component of the driving pressure acting at right angles to the disks, and it is evident that the resultant axial deflection causes also a relative displacement of the tooth line in the direction of the drive.

On account of this flexibility, an equal pressure is assured for all of the disks and an equal distribution of pressure along the driving line. The freedom from heavy overloads, which in solid gears is caused by errors in cutting at some part of the tooth surface and more especially at the ends of the teeth by the twisting of the pinion under load, makes it possible to use a finer pitch than in solid gears, and this, of course, increases the output for the same length of pinion. To understand this, it must be remembered that the shape or curvature of the teeth does not depend upon the diametrical pitch, but only on the gear diameters. The finer the pitch, the more driving points per unit length of face and the greater load which can be carried.

FIG. 3.



Curtis turbine and one-plane flexible type reduction gear for ship propulsion.

Gearing of this type has been applied to about 150 high-speed turbines for connection to electric generators, and the unqualified success of these sets after two years of hard service led the

S. S. "LA BREA"

Voyage	Date	Total distance in knots	Average speed in knots per hour	Total barrels delivered	Name of port	Total fuel used steaming on voyage in barrels	Total barrels per knots steaming	Total barrels used in port	Total barrels per knot steaming and in port	Time in port hours	Barrels discharged per hour	Cost at 80 cents per barrel per knot steaming and in port (fuel)	Shaft horsepower-hours	Pounds of oil per shaft horsepower
1	March 9 to 15, 1916	650	9.5	62578	Oleum	574	.883	142	1.10	36½	1714	$ .88	116000	1.67
2	March 15 to 26	2037	11.33	73600	Seattle	1459	.716	152	.79	37½	1962	.632	505000	.941
3	March 28 to April 6	2108	11.01	64676	Vancouver	1584	.751	155	.824	26	2487	.659	530000	1.01
				8642	Seattle					13½	640			
4	April 8 to May 16	92545	10.97	52109	Taltal	6896	.745	117	.757	33¾	1544	.605	2330000	1.00
				19045	Antofagasta					15½	1228			
5	May 17 to 23	450	11.20	77292	Oleum	321	.713	134	1.01	39	1980	.808	118000	.911
6	May 24 to July 1	91965	10.65	71824	Antofagasta	6900	.75	109	.762	25	2660	.609	2200000	1.06
7	July 1 to Aug. 9	9184	10.39	71791	Port San Luis to Antofagasta, Chili, and return	6875	.748	107	.76	42.3	1697	.609	2230000	1.04
	Average speed......		10.9											

Total pounds of oil steaming, 8,270,000. Total shaft horsepower-hours, 8,029,000. Pounds of oil per shaft horsepower-hour, 1.03.

S. S. "LOS ANGELES"

Voyage	Date	Total distance in knots	Average speed in knots per hour	Total barrels delivered	Name of port	Total fuel used steaming on voyage in barrels	Total barrels per knots steaming	Total barrels used in port	Total barrels per knot steaming and in port	Time in port hours	Barrels discharged per hour	Cost at 80 cents per barrel per knot steaming and in port (fuel)	Shaft horsepower-hours	Pounds of oil per shaft horsepower
1	April 9 to 15	423	9.4	67674	Oleum	556	1.31	164	1.70	64½	1099	$1.36	74600	2.48
2	April 16 to 25	1845	10.13	74739	Vancouver	1656	.897	218	1.01	33¼	2214	.808	394000	1.41
3	April 27 to May 25	6549	10.22	73734	Panama	5579	.851	169	.877	46¼	1577	.701	1420000	1.315
4	May 26 to 29	220	9.1	72372	Oleum	221	1.00	123	1.56	41	1770	1.24	39000	1.88
5	May 30 to June 27	6348	10.6	72538	Balboa	5462	.86	159	.885	35	2072	.708	1460000	1.255
6	June 29 to Aug. 7, 1916	9151	10.24	71007	Port San Luis to Antofagasta, Chili, and return	8293	.906	186	.926	56.3	1261	.74	2130000	1.31
	Average speed.....		10.27											

Total pounds of oil steaming, 7,310,000. Total shaft horsepower-hours, 5,538,000. Pounds of oil per shaft horsepower-hour, 1.320.

General Electric Company to enter the marine field. Contracts have now been closed for about 250 marine propulsion sets, aggregating about 700,000 horsepower; about 40 of them are now in operation, and a few of them have gone about 100,000 knots with no replacement of either pinion or gears. Among the more important installations I may mention the cruising turbines for the battleship *Nevada,* which have now been in operation for almost two years. There are also about 25 2400-horsepower outfits in operation, as well as the two Luckenback boats, each of 4000 horsepower, which on their trial trip developed 5200 horsepower. Among the important sets now being built may be mentioned the equipmnt for U. S. Destroyer No. 69, having 21,000 horsepower and the U. S. S. *Salem*, having 20,000 horsepower.

The tables (pp. 330 and 331) show a comparison of the *La Breu* and *Los Angeles,* the former equipped with a geared Curtis turbine and the latter with a triple-expansion engine. It will be noted that the *La Brea* consumed only 1 pound of fuel oil per shaft horsepower, as compared with 1.31 pounds for the sister ship.

There is still another method of speed reduction; namely, the hydraulic gear as proposed by Doctor Föttinger in Europe, which consists of a centrifugal pump driving a water motor. With this arrangement he has obtained a combined efficiency of 90 per cent. with a speed reduction of 4 to 1. The efficiency falls off very rapidly, however, with higher ratios of speed reduction, and reaches about 80 per cent. with a speed ratio of 10 to 1. The mine-laying vessel *Koenigin Louise* was equipped in this way, this vessel having been sunk during the present war. Rapid wear and small clearances are the principal difficulties with this method of propulsion.

This paper has described to you some of the latest developments in marine propulsion and shows that the United States has again taken the lead in marine engineering. With the activities now going on in shipbuildng in this country, we can look forward in the near future to even greater results.

OCCLUDED GASES IN FERROUS ALLOYS.*

BY

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The rubber stoppers, when heated for several days at a temperature of 100° C., evolved only a few cubic centimetres of air, and it was therefore concluded that either the porcelain tube or the thermocouple evolved gas when heated in a vacuum. It had previously been noted by Fox, in his thesis for the degree of Master of Science at Massachusetts Institute of Technology, in 1886, that small amounts of gas either were dissolved in, or adhered to, porcelain. Before each determination the tube was allowed to stand under a vacuum for at least 48 hours in order that any free gas might be removed from the apparatus.

In preparing the material for Baker's first determinations, equal quantities of converted bar were melted in two crucibles in the same coke-fired oven. Aluminum was added to one sample. Both samples were then cast in moulds 6 cm. square, with the result that the ingot to which the aluminum had been added was sound, whereas the other ingot contained a number of blowholes. The chemical analysis of the ingots follows:

Element	Sound ingot, per cent.	Unsound ingot, per cent.
Combined carbon	0.810	0.900
Silicon	.080	.088
Manganese	.050	.096
Aluminum	.033	....
Sulphur	.028	.023
Phosphorus	.019	.019

Test bars were cut from each of these ingots and determinations made by heating the test bars ten days for eleven hours each day. In the case of the unsound steel, many of the blowholes were cut open before heating, in order that the gas might escape, since it was Baker's object to determine the gas evolved from the solid portion of the steel alone. It was found that the sound steel evolved a total of 91.86 c.c. of gas, or about 12.2 c.c. of gas per cubic centimetre of metal. Hydrogen was evolved first at 300° C. (dv/dt), reached a maximum at 600° C., decreased until 900° C. was reached, and then increased with the temperature. More than 90 per cent. of the gas evolved up to 500° C. was composed of hydrogen. Carbon monoxide was first evolved at 600° C. (dv/dt), increased to a maximum at 690° C., decreased to a minimum at 800° C., and finally increased with the higher temperature, as did hydrogen. Above 760° C. equal volumes of hydrogen and of carbon monoxide were evolved. In the case of the unsound steel similar changes were observed. The total volume of gas obtained from the defective steel, however, was much smaller than the volume obtained from the sound steel, only 42.09 c.c. of gas, or 5.2 c.c. of gas per cubic centimetre of metal, being evolved. Baker found that a maximum of gas evolution occurred at the points Ar_1, Ar_2, Ar_3 with both samples of steel, this maximum being much greater in the case of the sound steel. He concluded that the increase in (dv/dt) must have been due to carbon monoxide, since hydrogen was past its maximum. He was of the opinion that the increase could have been due to one of two causes: either the inferior solubility of carbon monoxide in gamma iron; or the decomposition of a chemical compound of carbon monoxide and iron.

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* Continued from page 198, vol. 185, February, 1918.

Baker next attempted to determine whether or not any action occurred between the steel samples and the porcelain of the tubes used. A blank determination was first conducted on one of the tubes, with the following evolution of gas upon heating:

	Volume in c.c.	Per cent. CO_2	Per cent. H	Per cent. CO	Per cent. CH_4	Per cent. N
1st period	4.21	22.80	55.58	15.67	3.31	2.61
2d period	3.51	9.37	65.62	18.81	1.42	5.11
3d period	3.16	12.97	73.41	5.69	.63	7.27
Total	10.88					

Each period of heating lasted for three hours.

Forty grammes of the sound steel previously used was then placed in a platinum boat and heated at 800° C. during 8 days for 11 hours a day. Fifty-three and sixty-seven hundredths c.c. of gas, or 10.5 c.c. of gas per cubic centimetre of metal was evolved (Table VI). This same steel heated in contact with the porcelain tube at a temperature of 802° C. evolved 9.03 c.c. of gas per cubic centimetre of metal (Table VI). Since these results correspond so closely, it was concluded that the fact that the steel was in contact with the tube in some of the experiments did not materially affect the quantity or the quality of the gas evolved.

A portion of the defective ingot was reheated to 1200° C., after which a 47.34-gramme sample of the ingot was heated to 827° C. in a vacuum for nine days. Fifty-two and ninety-four hundredths c.c. of gas, or 8.78 c.c. of gas per cubic centimetre, was evolved.

Samples were then cut from an ingot of soft steel before and after rolling. The composition of the steel was given as follows:

Element	Percentage
Carbon	0.13
Silicon	.011
Manganese	.37
Sulphur	.053
Phosphorus	.075

When heated in a vacuum to a temperature of about 950° C., the sample taken before rolling evolved 6.32 c.c. of gas per cubic centimetre of metal (Table VIII); the sample taken after rolling evolved 3.2 c.c. of gas per cubic centimetre of metal (Table IX). It was therefore concluded that mechanical work, such as rolling, did not change the composition of the gas evolved, but that it diminished the volume of the gas about 50 per cent.

Baker then determined the critical points of soft steel *in vacuo* with the following results:

Ac_1—722 Ac_2—758 Ac_3—867
Ar_1—682 Ar_2—760 Ar_3—846

The relation between these points is shown in the curves on page 338.

Baker's conclusions were as follows:

1. The amount of carbon monoxide evolved from steel is not proportional to the carbon in the steel.

2. There is no appreciable dissociation pressure, such as we should expect to find if carbon monoxide and hydrogen were due to the decomposition of compounds of iron with these gases.

3. Gases are imprisoned in the pores of steel, and, when the

TABLE VI

BAKER.

Steel without Blowholes. Weight 69.31 Grammes.

Temp. C.	Volume in Cubic Centimetres						Percentage Composition.				
		CO_2	H_2	CO	CH_4	N_2	CO_2	H_2	CO	CH_4	N_2
519	6.53	0.07	6.37	0.07	0.02	0.00	1.07	97.57	1.07	3.30	0.00
600	10.67	.19	8.44	2.00	.07	.00	1.78	79.00	18.74	.65	.00
672	12.87	.35	8.07	4.40	.07	.00	2.71	62.70	34.18	.54	.00
688	22.91	.75	6.96	15.02	.12	.03	3.27	30.38	65.56	.52	.13
719	12.61	.07	4.74	7.72	.06	.01	.55	75.58	61.22	.47	.08
765	6.71	.02	3.35	3.26	.05	.02	.29	49.92	48.58	.74	.29
802	4.29	.00	2.24	1.97	.08	.00	.00	52.21	45.92	1.86	.00
865	4.59	.05	2.24	2.22	.08	.00	1.00	48.80	48.36	1.74	.00
936	5.04	.03	2.53	2.42	.07	.00	.59	50.19	48.01	1.38	.00
979	5.64	.01	2.83	2.75	.04	.00	.17	50.17	48.75	.70	.17
T't'l	91.86	1.54	47.77	41.83	.66	.01					

Steel with Blowholes. Weight, 63.261 Grammes.

530	3.28	0.09	3.04	0.06	0.05	0.04	2.74	92.68	1.82	1.52	1.22
603	2.96	.06	2.70	.08	.06	.06	2.02	91.21	2.70	2.02	2.02
681	4.36	.06	2.16	2.01	.15	.03	1.37	48.39	46.10	3.45	.69
696	5.45	.02	1.49	3.85	.05	.04	.36	27.34	70.64	.91	.73
720	5.04	.03	1.84	3.11	.06	.00	.59	36.50	61.70	.19	.00
762	3.80	.02	1.87	1.81	.09	.01	.52	49.21	47.63	2.37	.26
825	3.98	.02	2.01	1.87	.07	.01	.50	50.50	46.98	1.75	.25
893	4.24	.03	2.18	1.93	.10	.00	.71	51.41	45.51	2.35	.00
944	4.48	.02	2.32	2.08	.05	.01	.45	51.78	46.42	1.11	.22
1016	4.50	.02	3.38	1.05	.05	.00	.44	75.11	23.33	1.11	.00
T't'l	42.09	.37	22.99	17.85	.73	.20					

Baker-Steel in the Platinum Boat. Weight, 40 Grammes.

Temp. C.	Volume of the Gas in Cubic Centimetres.						Composition of the Gas in Per Cent.				
		CO_2	H_2	CO	CH_4	N_2	CO_2	H_2	CO	CH_4	N_2
509	3.98	...	3.90	.01	...	.07	0.00	97.99	0.25	0.00	1.75
642	6.37	.06	5.98	.02	.25	.06	.94	93.87	.31	3.92	.94
664	6.18	.15	4.60	1.13	.27	.03	2.42	74.43	18.28	4.35	.49
703	7.75	.33	3.97	3.13	.26	.06	4.26	51.22	40.38	3.35	.77
727	10.72	.32	3.34	6.85	.21	.00	2.98	31.15	63.89	1.95	.00
758	12.06	.18	2.61	9.04	.21	.02	1.49	21.64	74.95	1.74	.16
800	6.61	.02	2.93	3.33	.28	.05	.30	44.32	50.37	4.23	.76
889	5.12	.00	2.55	2.39	.12	.06	.00	49.80	46.68	2.34	1.18

TABLE VI.

Baker-Steel after Re-heating. Weight, 47.34 Grammes.

Temp. C.	Volume of the Gas in Cubic Centimetres.						Composition of the Gas in Per Cent.				
		CO_2	H_2	CO	CH_4	N_2	CO_2	H_2	CO	CH_4	N_2
481	4.66	.01	4.52		0.01	0.03	0.21	96.99		2.14	.64
583	4.50	.01	4.34		.14	.01	.22	96.44		3.11	.22
640	5.57	.06	4.43	.86	.19	.03	1.07	79.53	15.44	3.41	.54
680	5.63	.13	3.20	2.06	.23	.01	2.31	56.83	36.58	4.08	.17
729	11.22	.29	4.47	5.89	.41	.16	2.58	39.84	52.49	3.65	1.42
775	11.44	.14	2.64	8.30	.29	.07	1.22	23.07	72.55	2.53	.62
827	9.92	.11	2.58	6.91	.28	.04	1.10	26.00	69.65	2.82	.41
903	5.51	.00	2.86	2.38	.24	.03	.00	51.90	43.19	4.35	.54
978	8.09	.02	3.81	4.09	.16	.01	.24	47.09	50.55	1.93	.12

TABLE VII.

Baker—Results of Previous Three Tables and Average Analyses of Gas.

Wt. of Steel. g.	Cond. of Steel.	Max. Temp. C.	Vol. of gas, cc.	Vol. of gas per g.	Average Per Cent. Composition.				
					CO_2	H_2	CO	CH_4	N_2
69.31	Contact with tube	802	79.65	1.14	1.89	52.43	44.97	.58	.07
40.00	In Platinum boat	800	53.67	1.34	1.34	50.76	43.93	2.76	.54
47.34	Reheated and in contact with tube	827	52.94	1.11	1.42	49.67	45.57	2.65	.69

TABLE VIII.

Baker—Ingot, C. 13 Per Cent., Weight, 66.6573 Grammes.

Temp. C.	Volume of the Gas in Cubic Centimetres.						Composition of the Gas in Per Cent.				
	Sum	CO_2	H_2	CO	CH_4	N_2	CO_2	H_2	CO	CH_4	N_2
411	2.79	0.04	2.68	....	...	0.07	1.43	96.05	....	...	2.51
525	2.37	.01	2.33		.01	.02	.42	98.31	.42		.84
609	6.05	.01	5.90	.13	.01	.00	.16	97.52	2.15	.16	.00
667	4.92	.08	4.58	.27	.01	.00	1.62	93.09	5.48	.19	.00
720	7.26	.31	3.64	3.29	.02	.00	4.27	50.13	45.31	.27	.00
786	17.19	.24	5.24	11.63	.07	.00	1.40	30.48	67.65	.40	.00
836	13.20	.10	4.19	8.67	.13	.11	.76	31.74	65.68	.98	.83
885	7.03	.01	3.33	3.54	.13	.02	.14	47.37	50.35	1.84	.28
965	8.03	.01	3.99	3.89	.13	.01	.12	49.68	48.44	1.61	.22

TABLE IX.

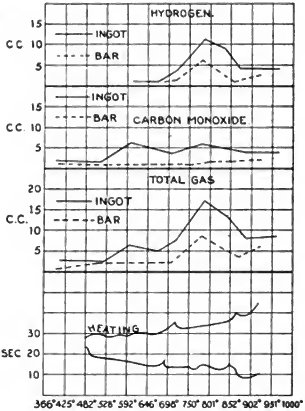
Baker—Bar of Steel. Weight, 67.7358 Grammes.

Temp. C.	Volume of the Gas in Cubic Centimetres.						Composition of the Gas in Per Cent.				
	Sum	CO_2	H_2	CO	CH_4	N_2	CO_2	H_2	CO	CH_4	N_2
435	1.61	0.06	1.46	0.02		0.07	3.72	90.68	1.24		4.34
535	2.21	.02	2.14	...		.05	.91	96.83	....		2.26
610	1.85	.00	1.71	.09		.05	.00	92.43	4.86		2.70
679	2.35	.02	1.80	.42	.02	.09	.85	76.59	17.87	.85	3.83
722	2.75	.03	1.43	1.25	.00	.04	1.09	52.00	45.45	.00	1.45
788	9.14	.11	2.48	6.48	.00	.07	1.20	27.13	70.89	.00	.76
823	7.13	.07	2.43	4.55	.01	.07	.98	34.08	63.81	.14	.98
872	3.96	.02	1.81	2.09	.01	.03	.50	45.70	52.78	.25	.76
927	5.25	.00	2.48	2.60	.00	.17	.00	47.23	49.52	.00	3.23

steel is reheated *in vacuo,* they are driven out. This conclusion is based on the following facts:

(*a*) Hydrogen and carbon monoxide, of which the gas is almost entirely composed, are evolved in the order of their densities. In the case of diffusion the evolution would occur in this manner.

(*b*) The largest quantities of gas are evolved at the critical points. Molecular agitation would tend to increase the rate of evolution.



Baker.

(*c*) Drilling with blunt drills causes more gas to be evolved than does drilling with sharp drills.

(*d*) Mechanical operations, such as rolling, greatly decrease the quantity of gas retained.

Practically all of the investigators named so far worked with iron and steel. Guillemin and Delachanal,[26] however, obtained a number of results with copper alloys, brass, and tin. Special metals of French, German, and Belgian manufacture were investigated at 1000° C., with the following results:

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[26] *Compt. rend.*, **151**, 1910, pp. 881–883; *Metallurgie*, **8**, 1911, pp. 338–339.

Material	Gas volume / Metal volume	Per cent. CO_2	Per cent. H	Per cent. CH_4	Per cent. CO	Per cent. N
Special brass	1.12	1.9	91.53	2.38	3.56	0.63
Special brass	.84	.3	79.1	1.4	17.9	1.3
Special brass	26.00	8.7	59.9	1.3	29.5	.6
Al brass	24.2	2.06	95.84	.6	.9	.6
Wrought brass	2.3	2.3	92.6	2.3	.2	2.6
Wrought brass	.43	3.2	93.3	1.2	1.1	1.2
Bronze	7.3	16.2	59.9	7.2	16.4	.3
Bronze	.78	86.7	13.0	.....	.....	.3
Phosphor bronze	.28	58.0	40.8	.....	.....	1.2
Commercial Sn	.19	14.5	63.0	5.4	12.3	4.8
Gray Sn	.21	14.7	71.7	4.9	.5	8.2

From the results just given, these investigators arrived at the following conclusions:

1. The special wrought brass evolved particularly large volumes of gas (1 to 30 times the volume of the metal used), and this gas consisted mostly of hydrogen, carbon dioxide, and carbon monoxide.
2. In perfect castings the gas was composed chiefly of hydrogen, this constituting 90 per cent. of the total volume evolved.
3. In the imperfect alloys, in addition to hydrogen, much carbon monoxide and some carbon dioxide were found.
4. The forged pieces contained less gas than the cast pieces.
5. In the case of perfect pieces of wrought brass, the occluded hydrogen seemed to have no undesirable effect on the mechanical properties of the alloys.
6. Phosphor bronze contained less gas, particularly hydrogen and carbon monoxide, than did the other alloys. (Phosphorus always hinders the solution of hydrogen in metals.)
7. Commercial tin contained only a small volume of gas, made up of carbon dioxide, carbon monoxide, and hydrogen.

Dr. P. L. T. Heroult[27] has expressed the following opinion concerning the origin of the gases found in steel:

"Blowholes in steel ingots invariably contain hydrogen and nitrogen, often with only traces of carbon monoxide. On the other hand, it is well known that when a thoroughly sound steel ingot is placed in a vacuum chamber a certain amount of the above-named gases will be exhaled or thrown off." He then adds that, " although it is popularly thought that the amount of gases in steel depends upon the process used in preparing the steel, nevertheless, this is an erroneous impression, since the quantities of gases evolved from different kinds of steel are about the same."

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[27] *Trans. Am. Electrochem. Soc.*, 17, 1910, pp. 135–137.

Finally he says: "Blowholes are the result of disengagement of carbon monoxide, with the exception, of course, of accidental blowholes due to the poor condition of the moulds.

" This carbon monoxide does not preëxist in the steel: it is only produced when the steel cools down and part of it has become solid. Steel that will produce blowholes contains, in the molten state, carbon and, at the same time, iron protoxide. So long as the steel is molten and hot, these two bodies can be kept apart, and for each temperature and composition of steel there is a state of equilibrium at which no chemical reaction takes place. The heat is then what the Germans call 'gar'; that is to say, 'dead-melted.' If the temperature is increased, the reducing action of carbon will be intensified and carbon monoxide will be evolved. If, on the contrary, the temperature is lowered, nothing happens until the steel gets partially solidified, with the effect that carbon and iron protoxide are crowded into a small space with what we might call the mother-liquor, and monoxide of carbon is evolved. The blowholes produced are filled with carbon monoxide at a high temperature. As this gas cools down, however, it creates a vacuum, and we then repeat the conditions of the ingot in the vacuum chamber.

" You can understand now why it is that blowholes are found containing hydrogen and nitrogen. Steel does not contain any gases to amount to anything, and whatever small quantities it does contain are not injurious or detrimental to its quality. As a matter of fact, Bessemer steel, either acid or basic, which has every possible opportunity of absorbing gases, does not contain any more than any other steel."

An interesting research on the solubility of gases in metals was conducted by Dr. A. Sieverts.[28] He sought to determine: (1) The influence of temperature on the solubility of gases at constant, atmospheric pressure; (2) the diffusion of gases through metals; (3) the influence of the surface of metals on the solubility of gases; (4) the influence of the addition of a second metal on the solubility of gases; (5) the relation between solubility and gas pressure.

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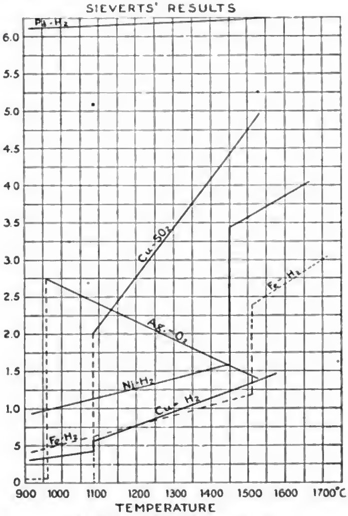
[28] *Zeit. für Elektrochemie*, 16, 1910, pp. 707-713.

In making his determinations, Sieverts brought gases into contact with metals under different temperatures and pressures, and then measured the volume of gas absorbed. The means by which this operation was carried out were not disclosed. For temperatures up to 1350° C. a platinum foil oven was used; for temperatures between 1350° and 1700° C. a silundum furnace was used. Tubes of biscuit porcelain were also found to be suffi-



Mg H_2 dissolved by 100 grammes metal.
Mg O_2 6.5 dissolved by 1 gramme Ag.
Mg SO_2 dissolved by 0.5 gramme Cu.

ciently impervious to gases at temperatures above 1400° C. to introduce no serious error in numerical results.

The results of Sieverts's experiments were many and varied. It was discovered that a number of metals, tested in both solid and molten states, dissolved neither nitrogen nor hydrogen. This list of metals included cadmium, thallium, zinc, lead, bismuth, tin, antimony, aluminum, silver, and gold. Nitrogen was especially insoluble in copper, nickel, and palladium. Above 800° C. aluminum was found to form a nitride. Carbon dioxide and carbon monoxide were insoluble in copper. Methane was decomposed by molten copper with the separation of graphitic carbon. Above 1000° C. nickel absorbed carbon monoxide. Iron acted in a similar manner. The manner in which this carbon monoxide was held in solution was not discovered, but it was hoped that this might be disclosed later. Hydrogen appeared to possess the most general solubility. It was found possible to determine the amounts of hydrogen present in palladium, iron, nickel, cobalt, and copper. Oxygen could be detected in silver alone. In the case of other metals it was found that oxygen formed solutions of oxides, which possessed exceedingly low decomposition voltages. In special cases only was nitrogen found to possess any marked solubility in metals. When powdered iron, reduced in nitrogen, was heated to 900° C. varying amounts of the gas, dependent upon the temperature and the pressure, were suddenly absorbed. The metal was then allowed to cool, and the gas was evolved at 900° C. as quickly as it had been absorbed. It thus appeared that nitrogen was absorbed by gamma iron alone. With commercially pure iron wire and with electrolytic iron different results were obtained. Above 900° C. nitrogen was absorbed very slowly. When the metal was cooled no nitrogen was evolved, indicating that a nitride had probably been formed.

In the majority of cases in which gases were found to be soluble in metals the solubility increased very rapidly with the temperature. This increase was directly proportional to the rise in temperature. The systems copper-hydrogen, iron-hydrogen, nickel-hydrogen, and copper-sulphur dioxide were examples of cases with which this increase occurred. There were, however, some exceptions to the rule. With the system silver-oxygen, for instance, small amounts of the gas were dissolved by the solid silver. When the melting-point of silver was attained, a large volume of oxygen was absorbed, and the solubility then decreased with a rise in temperature.

Sieverts next investigated the ability of gases to diffuse through metals. It was discovered that oxygen would diffuse through silver, and that hydrogen would diffuse through platinum. In the latter case little or none of the gas was absorbed. It was also determined that hydrogen would not diffuse through aluminum, and that carbon monoxide would not diffuse through copper. In this respect, sulphur dioxide acted similarly to carbon monoxide. At 1000° C. carbon monoxide appeared to diffuse through nickel and iron to a very slight extent.

In determining the effect produced on the solubility of gases in metals by differences in the surfaces exposed to the gases, nickel in the form of solid pieces, wire, and powder was saturated with hydrogen. It was determined that equal weights of the three different forms of the metal absorbed equal volumes of the gas. The same result was obtained when iron, copper, and palladium in different forms were exposed to gases.

It was also determined that the solubility of gases in alloys was equal to the average solubilities of the gases in the constituents of the alloys; that is, as much gas was absorbed by an alloy as was absorbed by the separate constituents of the alloy.

From the foregoing results Doctor Sieverts deduced the following general rule for determining the amounts of gases dissolved by metals: The absorbed mass (m) is proportional to the square root of the pressure (p); or $m = p \times$ const.

This rule was proved for the following systems:

Hydrogen and (palladium, solid; nickel, solid and molten; iron, molten; copper, molten; copper alloys, molten).

Oxygen and (silver, molten; gold-silver, molten).

Nitrogen and (gamma iron, solid).

Sulphur dioxide and (copper, molten).

Attention is directed to the close analogy between the above formula of Sieverts and the van't Hoff hypothesis: $C_1 = C_2^n \times$ const. Curves showing the numerical results of the preceding investigations are shown in the following diagram.

G. Charpy and S. Bonnerot[29] discovered that certain samples of steel evolved gas when heated to 950° C. in a vacuum. In their first series of determinations steel manufactured by the Siemens-Martin process was used in the two forms: plates two millimetres in diameter, and 0.1 millimetre turnings. Gas was evolved, as shown in the following table:

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[29] *Compt. rend.*, 152, 1911, pp. 1247–1250.

Time of heating	*dv/dt* in c.c. per gramme per hour		Total volume gas per gramme	
	Plate	*Turnings*	*Plate*	*Turnings*
After ½ day	0.01	0.06	0.03	0.16
After 1½ days	.025	.015	.25	.29
After 2½ days	.008	.008	.33	.37
After 3½ days	.003	.003	.36	.40

The following table shows the results obtained in later determinations:

Material	Per cent. by volume of gas obtained	
	After 5 hours	After 3½ days
Steel (0.9 per cent. C.)	0.65	0.98
Steel (1.05 per cent. C.)	.55	.75
Steel (1.2 per cent. C.)	.53	.69
Steel (1.0 per cent. C.)	.24	.31
Steel	.29	.34
Steel (0.07 per cent. C.)	.40	.70
Steel (0.04 per cent. C.)	.79	1.06

It will be noticed that the gas volumes obtained in these experiments were comparatively small.

In 1912, G. Wesley Austin,[30] of the University of Birmingham, published a method for the determination of occluded gases very similar to the method finally designed by Parry over thirty years before. Having concluded that the chief error in former investigations lay in the fact that the material used in the determinations was not fused, and that thus there was no means of telling whether or not all the gas was evolved from the metal, he perfected an apparatus by means of which his samples could be fused in a vacuum. The necessary high temperature was attained by passing an alternating current of 1000 to 20,000 ampères directly through the samples. By this method it was found possible to gradually increase the temperature until the metal fused. Below is given a sketch of Austin's apparatus:

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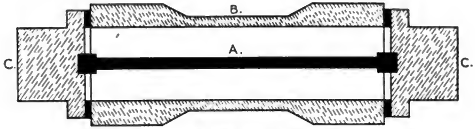
[30] *Jour. of Iron and Steel Inst.*, **86**, 1912, 2, pp. 236–240.



A. Specimen. *B*. Steel tube. *C*. Cu electrodes.

"The envelope of the furnace was a (weldless) steel tube, 20 cm. long, 9 cm. in internal diameter, and 2 cm. thick. The tube was closed by flanged copper electrodes forced against the ends of the tube by large, hollow steel nuts. The contact surfaces were machined and cut with fine V-grooves, into which insulating packing was compressed. The electrodes were water-cooled, and a seamless capillary copper tube, screwed and sweated into the steel pipe, connected the interior with the vacuum pump.

"The specimens examined were turned from round bars 1 inch in diameter and 8¾ inches long. The middle 6 inches of these bars was turned down to ½ inch in diameter, this being the portion which it was intended to fuse. It was found that practically all of this 6 inches could be fused if, when the melting-point was approached, the current was shut off for a few moments and then thrown on again, thus allowing the heat to distribute itself along the bar. Each heating was conducted in three stages of one-half hour each, the first stage being to 900° C., the second stage to 1100° C., and the third stage to fusion. From this procedure the following results were obtained."

Material	Analysis (per cent.)					Gas analysis (per cent.)			Quantity of gas
	C	Si	Mn	S	P	CO_2	CO	H, N, etc.	c.c. per gramme
Cast iron	3.5	2.50	.60	.05	1.50	3.1	23.0	73.9	0.27
Crucible steel	1.1	.24	.39	.02	.02	.4	44.2	55.4	1.73
Medium	.49	.35	.72	.02	.02	.6	45.1	54.3	1.35
Open-hearth mild steel	.09	.05	.75	.05	.05	*5.6 †.7	31.5 43.0	62.9 46.3	.66 = .97 .31
Bessemer steel	.05	.09	.29	.06	.05	*5.2 †3.8	59.8 43.5	35.0 52.7	.87

* Extracted during first stage of heating.
† Extracted during remaining stages.

From the results of his investigations Austin arrived at two conclusions: the volume of gas evolved from cast iron is relatively much smaller than from steel, and the percentage of carbon monoxide is considerably lower; the higher the carbon content of the steel, the larger the amount of evolved gas.

The volumes of gas obtained during Austin's experiments were not nearly so large as might have been expected in heating the metal to its fusing-point. This small gas volume might have been due to the fact that the gas did not have time to escape from the test bars, the fusing of the metal naturally resulting in a sudden lowering of the temperature, due to the break in the circuit. There was another source of error in the steel envelope surrounding the test bars. Part of the gas obtained might easily have been evolved from this envelope instead of from the bars, and part of the gas liberated from the bars might easily have been absorbed by the steel envelope and also by the unfused portion of the bar.

About this time (1913) Dr. W. Herwig[31] became interested in the question of nitrogen in iron. The blisters formed on plates during rolling and annealing were examined and were found to contain 90 per cent. of nitrogen. Nitrogen was determined by a modification of the Kjeldahl process. It was concluded that the gas present in the blisters had come from the iron and not from the air, and that, in the iron, it was present in the combined form. Twenty grammes of steel turnings, when heated to 800° C. for 12 hours in a stream of hydrogen, evolved both nitrogen and ammonia. The nitrogen content of the turnings fell from 0.018 per cent. to 0.002 per cent.

Experiments were conducted with the object of determining the gases which had been retained by liquid cast iron.

(*a*) Twenty grammes of white pig iron of the following composition was used:

Element	Percentage
Carbon	2.61
Phosphorus	1.61
Manganese	.67
Sulphur	.162
Nitrogen	.009
Silicon	.31

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[31] *Stahl u. Eisen*, 33, 1913, pp. 1721–1727.

When this iron was heated to 900° C. for 5 hours in a porcelain tube, 18 c.c. of hydrogen and 8 c.c. of carbon monoxide were evolved.

(*b*) Twenty grammes of gray pig iron of the following composition was heated:

Element	Percentage
Carbon	3.17
Phosphorus	1.97
Manganese	1.42
Silicon	.92
Sulphur	.026
Nitrogen	.004

When this iron was heated under conditions similar to the conditions under which the white pig iron had been heated, 7.4 c.c. of hydrogen and 0.8 c.c. of carbon monoxide were evolved. In both cases small quantities of carbon dioxide and of oxygen were also evolved. The gases were evolved irregularly, small explosive evolutions occurring at the "arrest points" on the cooling curves.

Steel turnings, when heated in pure nitrogen, did not absorb any gas, but when heated in a mixture of hydrogen and nitrogen the nitrogen content of the steel rose to a maximum point beyond which it seemed impossible to pass. In some experiments the maximum nitrogen content ranged from 0.032 to 0.052 per cent. for different samples. The presence of nitrogen in basic steel was thus explained by the supposition that a combination of the nitrogen in the blast and the hydrogen in the pig yielded ammonia. This gas was in turn decomposed by the steel, yielding iron nitride.

Herwig's numerical results were, on the whole, much lower than the results obtained by a number of previous investigators.

In 1910[32] P. Goerens conducted a number of investigations on occluded gases, using a quartz tube heated electrically by a Heræus resistance oven to 1100° C. He noted the importance of keeping the iron out of contact with the quartz, since at 950° C. a very noticeable reaction between these two materials occurs. The materials on which the investigations were conducted were in the form of filings. Temperatures were measured by means of a Le Chatelier pyrometer. Goerens used 36 different kinds of iron

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[32] *Metallurgie*, 7, 1910, pp. 384-395.

TABLE X.
Showing Goerens' Results.

No. of Det.	Temp. C.	Time heated min.	Weight of metal G.	Gas vol. in c.c. at 0° and 76 mm.	Vol. of gas per vol. of Fe. c.c.	Composition of metal in per cent.					Composition of gas in per cent.				C.c. of gas per c.c. of metal			
						P	Mn	C	S	Si	CO_2	CO	H_2	N_2	CO_2	CO	H_2	N_2
1	850 880	20	30.29	4.74	0.88	0.074	0.23	0.05	0.057	0.019	20.1	42.1	24.2	13.6	0.18	0.37	0.21	0.12
2	900 950	15	22.17	9.52	3.38	.079	.4	.067	.038	.021	7.75	76.3	6.0	9.95	.26	2.58	.20	.34
3	900 950	15	12.9	4.94	3.01	.079	.4	.067	.038	.021	4.9	74.9	6.5	13.7	.15	2.36	.20	.55
4	900 930	15	18.21	4.51	1.95	.103	.28	.056	.066	.014	13.8	45.1	31.8	9.3	.27	.88	.62	.18
5	900 930	15	20.22	11.56	4.1	.103	.49	.083	.05	.05	14.7	65.1	12.2	8.0	.60	2.67	.50	.33
6	900	15	13.74	2.51	1.44	.07	.25	.039	.062	.008	9.7	51.8	25.5	13.0	.14	.75	.37	.19
7	900 940	20	9.62	4.03	3.30	.072	.39	.072	.049	.007	8.8	69.9	11.0	10.3	.27	2.46	.39	.41
8	890 910	30	12.19	2.04	1.2	.072	.39	.072	.049	.007	.3	75.9	11.1	12.7	.004	.91	.13	.16
9	880 890	25	17.51	3.34	1.5	.086	.37	.075	.051	.015	6.5	76.6	11.3	5.6	.10	1.15	.17	.08
10	900 925	30	17.88	6.85	3.9	.112	.89	.302	.037	.021	1.5	77.2	4.5	16.8	.06	3.01	.18	.65
11	900 940	30	20.57	1.55	.59	.086	.28	.043	.074	.013	9.5	64.1	15.9	10.5	.06	.37	.09	.07
12	900	30	17.6	10.98	4.4	.106	.43	.190	.065	.017	4.3	79.7	3.5	12.5	.19	3.51	.15	.55
13	900 960	15	9.15	2.61	2.1	.103	.28	.056	.066	.014	24.8	46.5	17.4	11.3	.52	.98	.37	.24
14	950 980	12	7.67	2.64	2.7	.....	.49	.083	.050	.05	5.8	73.4	7.8	13.0	.16	1.98	.21	.35

15	1000	15	9.08	1.4	1.2	.068	.288	.036	.064	.01	9.9	68.2	20.1	1.8	.12	.82	.24	.02
16	900	15	9.99	2.67	2.1	.077	.476	.056	.053	.016	1.1	....	22.2	.....	.02	....	.47	....
17	930 960	20	10.58	4.79	3.6	.077	.475	.056	.053	.016	10.4	68.5	9.2	11.9	.37	2.45	.33	.44
18	930	15	10.00	3.68	2.5	.077	.476	.056	.053	.016	9.5	65.1	12.0	13.3	.22	1.63	.30	.35
19	900 930	30	14.79	2.43	1.3	.085	.12	.058	.043	.017	7.5	80.1	7.1	5.3	.10	1.04	.08	.07
20	900	30	32.66	6.49	1.3	.069	.12	.076	.031	.023	6.4	84.8	4.7	4.1	.08	1.10	.05	.06
21	900 930	0	13.18	3.30	1.9	.098	.22	.15	.042	.169	4.7	78.3	11.7	5.3	.69	1.49	.22	.10
22	900	35	16.79	3.56	1.7	.025	.30	.093	.054	.003	2.2	85.6	7.4	4.8	.04	1.44	.12	.10
23	900	30	18.99	4.49	1.9	.031	.93	.138	.037	.35	3.4	82.8	8.1	5.7	.06	1.57	.15	.12
24	850	20	9.60	1.92	1.6	.040	.93	.138	.037	.35	3.8	74.9	13.9	7.4	.06	1.20	.22	.12
25	900	20	9.91	1.09	.85	.045	.93	.142	.039	.236	1.7	58.4	15.4	14.5	.01	.58	.13	.13
26	900	30	15.27	3.3	1.7	.018	.39	.108	.039	.003	5.0	78.5	7.4	9.1	.09	1.33	.13	.15
27	900 930	15	13.5	3.18	1.8	.023	.60	.114	.033	.003	2.6	83.2	4.7	9.5	.05	1.5	.09	.16
28	900 930	25	16.74	6.98	3.3	.024	.58	.112	.031	.001	4.2	81.7	10.2	3.9	.14	2.7	.34	.13
29	910 930	20	14.62	3.15	1.7	.045	.49	.14	.052	.006	5.4	79.4	6.3	8.9	.09	1.35	.10	.16
30	900 930	15	15.45	3.44	1.7	.045	.77	.175	.041	.007	4.5	79.8	5.6	10.1	.08	1.36	.10	.16
31	910	20	13.75	3.96	2.3	.049	.65	.137	.042	.011	3.5	78.6	6.7	11.0	.08	1.81	.15	.26
32	930 970	15	11.64	4.87	3.0	.038	.43	.40	.006	.153 W. .24	.8	81.6	6.1	11.5	.02	2.45	.18	.35
33	920 960	15	9.15	2.25	1.9	.038	.43	.40	.006	.153 .24	1.3	69.2	18.6	10.9	.02	1.31	.35	.22
34	950 960	15	9.47	1.78	1.5	.031	.34	.42	.005	.155 .57	.7	71.6	7.2	20.5	.01	1.07	.11	.31
35	900	35	18.15	14.3	6.1	.....	.....	.....	.....	.....	3.7	72.7	8.3	15.3	.22	4.45	.51	.92
36	850	20	16.23	17.05	8.2	.090	.085	3.65	.005	.014	11.5	70.5	11.1	6.9	.95	5.80	.91	.56

NOTE.—Description of material on next page.

DESCRIPTION OF THE MATERIAL USED BY GOERENS.

Thomas Iron—Charge No. 1.

No. 1. Before the addition of ferromanganese.

No. 2. After the addition of ferromanganese.

No. 3. After the addition of ferromanganese, after the same had been poured 4 minutes.

Thomas Iron—Charge No. 2.

No. 4. Same as No. 1.

No. 5. Same as No. 2.

Thomas Iron—Charge No. 3.

No. 6. Same as No. 1.

No. 7. Same as No. 2.

No. 8. Same as No. 3—poured 8 minutes.

Thomas Iron—Charge No. 4.

No. 9. Same as No. 1.

No. 10. Same as No. 2—after addition of ferromanganese and spiegel.

Thomas Iron—Charge No. 5.

No. 11. Same as No. 1.

No. 12. Same as No. 2.

Thomas Iron—Charge No. 6.

No. 13. Same as No. 1.

No. 14. Same as No. 2.

Thomas Iron—Charge No. 7.

No. 15. Same as No. 1.

No. 16. Same as No. 2.

No. 17. Same as No. 2—taken from upper part of sample.

No. 18. Same as No. 2—taken from under part of sample.

Electro-Steel.

No. 19. After the removal of hammer scale.

No. 20. After the removal of the second scale of ferrosilicon.

No. 21. Determination on prepared steel.

Siemens-Martin Iron—Charge No. 1.

No. 22. Shortly before addition of ferromanganese.

No. 23. Shortly after addition of ferromanganese—ferrosilicon added in mold.

No. 24. After the preparation at pouring of first block.

No. 25. After the preparation at pouring of last block.

Siemens-Martin Iron—Charge No. 2.

No. 26. Shortly before preparation.

No. 27. Shortly after preparation.

No. 28. Shortly after preparation—at pouring of the last block.

Siemens-Martin Iron—Charge No. 3.

No. 29. Same as No. 26.
No. 30. Same as No. 27.
No. 31. Same as No. 28.
No. 32. Crucible steel, unpurified—Charge No. 1.
No. 33. Crucible steel, unpurified—Charge No. 1.
No. 34. Crucible steel, unpurified—Charge No. 2.
No. 35. Determination on rail.
No. 36. Swedish pig iron.

and steel in his investigations, and determined that the ratio of the volume of gas obtained to the volume of the metal used varied from 0.88 to 8.2, averaging, however, from 1.7 to 3.0. Seventy to eighty per cent. of this gas was carbon monoxide, 5 to 15 per cent. was hydrogen, and 7 to 14 per cent. was nitrogen. Table X (pp. 348 and 349) gives these results in detail. Goerens believed that the carbon monoxide evolved was due to the action of the carbon and oxygen originally present in the steel as carbide and as oxide. In proof of this theory he performed the following experiment:

Some strongly oxidized iron, low in carbon, was heated in a vacuum until no more gas was evolved, and a sample of iron containing 3.6 per cent. carbon was treated similarly. The two samples were then mixed and heated in a vacuum, whereupon large volumes of carbon monoxide were at once evolved. Since such an action occurred at high temperatures, it was considered probable that it would occur to a certain extent even at ordinary temperatures.

In making the analysis of the gases driven off, the carbon dioxide was determined by absorption in potassium hydrate solution, the hydrogen and carbon monoxide were determined by explosion, and the nitrogen was determined by difference (see Table X, pp. 348 and 349).

Recently Goerens and Paquet[33] arrived at the same conclusion that Austin reached, namely, that all the gas could not be driven from metals unless the materials were fused. They therefore endeavored to determine some means by which iron and steel could be completely fused in a vacuum. Knowing that impurities lower the melting-point of iron, they decided to alloy iron with some substance which would reduce the melting-point to an easily attainable temperature. After experimenting with various metals, they concluded that the metals most suitable for their purpose were Kahlbaum's tin and antimony. When blank tests were conducted with these two metals, it was discovered that 100 grammes of antimony contained only 0.5 c.c. of gas, and that 100 grammes of tin contained only 0.6 c.c. of gas. In conducting determinations with iron and steel, 0.3 gramme of iron or steel, 0.3 gramme of antimony, and 3 grammes of tin were mixed in a crucible of magnesia and placed in a quartz tube, which was evacuated and heated electrically to 1150° C. for about two hours. Below is a sketch of the apparatus used:

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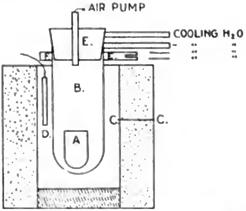
[33] *Ferrum*, 12, 1915, pp. 57–64; 73–81.



A. Mg crucible. *B*. Quartz tube. *C*. Elec. res oven. *D*. Thermoelement. *E*. Stopper H_2O cooled. *F*. H_2O cooled ring.

In the first series of determinations a sample of iron of the following composition was used.

Element	Percentage
Carbon	0.036
Manganese	.288
Phosphorus	.068
Sulphur	.064
Silicon	Trace

The following table shows the results obtained:

Experiment number	Location of sample in test piece	c.c. of gas per 100 grammes iron	Percentage of gases by weight			
			CO_2	CO	H_2	N_2
A	Edge	46	0.0027	0.0320	0.0010	0.0129
D	Edge	46	.0056	.0312	.0010	.0122
B	Middle	70	.0085	.0393	not determined	not determined
E	Middle	54	.0100	.0305	.0017	.0100
C	Edge	44	.0053	.0235	.0014	.0103
F	Edge	41	.0100	.0247	.0008	.0103
G	Edge	43	.0061	.0291	.0008	.0117

In a later group of experiments, using this method for liberating occluded gases, about 75 determinations were made with various kinds of iron and steel. The ratio of gas volume to metal volume was found to vary from 1 to 9, carbon monoxide forming the largest constituent, both by weight and by volume. A number of the results are tabulated (Table XI).

Thus far in this discussion no mention has been made of the electrolytic hydrogen occluded in metals. Graham[34] first made the observation that the best method of saturating any metal with hydrogen was to make the metal act in dilute acid as the negative electrode of a battery of six Bunsen cells. He gave the name hydrogenium to hydrogen absorbed in this process, and said that hydrogenium appeared to be the active form of hydrogen, just as ozone is the active form of oxygen.

Cailletet[35] decomposed electrolytically a solution of ferrous chloride rendered neutral by ammonia and obtained hard crystals of iron containing 0.028 per cent. of hydrogen.

TABLE XI

The Work of Goerens and Paquet.

Material No. 1—Rolled Molten Iron. Analysis: C, 0.08 per cent.; Mn, 0.4 per cent.; P, 0.082 per cent.; S, 0.048 per cent.

Determination	c. c. of gas per 100 grammes	Gas Analysis in per cent. by weight			
		CO_2	CO	H_2	N_2
No. 1	73	0.009	0.0735	0.00081	0.0058
No. 2	69	.0069	.0691	.00079	.0054
No. 3	68	.0069	.0692	.00051	.0071
No. 4	68	.0082	.0660	.00069	.0071
Average	69.5	.0078	.0694	.00070	.0062

Material No. 2—Rolled Molten Iron. Analysis: C, 0.06 per cent.; Mn, 0.4 per cent.; P, 0.08 per cent.; S, 0.04 per cent.

No. 1	44	0.0098	0.0320	0.00058	0.0110
No. 2	40	.0066	.0325	.00047	.0066
No. 3	40	.0098	.0335	.00059	.0042
No. 4	43 .	.0053	.0355	.00064	.0078
No. 5	42	.0058	.0346	.00065	.0066
No. 6	43	.0069	.0384	.00059	.0047
Average	42	.0073	.0344	.00050	.0068

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[34] *Proc. Roy. Soc.*, 17, 1869, p. 219.

[35] *Compt. rend.*, 80, p. 319.

Goerens and Paquet—Gas Content of Various Commercial Irons.

Material.	Composition of the Metal.							cc. gas per 100 g. Metal.	Composition of the Gas. Per Cent by Weight.				
	C	Mn	P	S	Si				CO_2	CO	H_2	N_2	Total
(a) *Thomas Iron.*													
1	0.05	0.36	0.11	0.045	.....	....	....	22	0.004	0.0196	0.0003	0.0029	0.0268
2	.08	.40	.08	.048	.....	....	....	40	.009	.0352	.0006	.0025	.0383
3	.05	?	.08	.040	.....			41	.0077	.0342	.0006	.0065	.0413
4	.05	.40	.03	.040	.....	....	....	49	.0061	.0393	.0006	.0122	.0521
(b) *Martin Iron.*													
5	.08	.40	.05	.030	.....			38	.0048	.0341	.0005	.0061	.0455
6	.15	.37	.06	.060	.....			46	.0048	.0410	.0009	.0024	.0443
7	.08	.44	.04	.037	.....			78	.0178	.0785	.0007	.0020	.0812
(c) *Electro-Steel.*													
8	.19	.50	.02	.012	.42	....	....	10	.0047	.0061	.0002	.0015	.0125
9	.08	.35	.01	.010	.09	4.34	1.10	13	.0082	.0015	.0007	.0000	.0104
10	.10	.38	.011	.010	.07	3.30	....	15	.0064	.0061	.0007	.0000	.0132
11	.15	.49	.011	.012	.45	....	....	25	.0058	.0092	.0012	.0048	.0210
12	.26	.43	.068	.023	.015	....	....	25	.0053	.0098	.0012	.0041	.0214
13	.10	.40	.010	.012	.10	....	....	28	.0053	.0207	.0008	.0019	.0287
14	.45	.38	.018	.022	1.27	....	....	32	.0058	.0167	.0013	.0042	.0280
15	.98	.45	.158	.075	.015	....	....	70	.0043	.0688	.0010	.0083	.0824
16	.71	.37	.018	.016	.23	....	....	73	.0106	.0684	.0010	.0078	.0878
17	1.35	.44	.020	.015	.19	....	.37	88	.0053	.0851	.0010	.0141	.1055
18	.10	.35	.009	.008	.17	3.62	.90	94	.0018	.0569	.0047	.0012	.0646
19	1.16	.38	.017	.016	.18	....	....	94	.0050	.0900	.0011	.0124	.1085
20	.33	.38	.026	.016	.10	3.06	1.94	105	.0109	.0708	.0039	.0056	.0912
(d) *Crucible Steel.*													
21	.38	.26	.056	.021	.19	....	.65	29	.0090	.0248	.0004	.0024	.0366
22	.84	.36	.041	.017	.15	....	....	41	.0058	.0391	.0007	.0015	.0471
23	.16	.44	.008	.008	.29	4.00	.91	50	.0032	.0271	.0022	.0053	.0378
24	.47	....	.020	.028	.....	2.98	1.29	51	.0200	.0257	.0016	.0068	.0541
25	.97	.14	.....	.010	.12	....	....	79	.0098	.0712	.0017	.0020	.0847
26	.27	.45	.010	.012	.24	4.00	1.30	152	.0096	.1290	.0041	.0082	.1509

William H. Johnson[36] confirmed the experiments of Graham, and in addition determined that occluded hydrogen possesses the property of making the iron or steel which contains it very brittle. As soon as the hydrogen is evolved by heating, the metal regains its former elasticity. Johnson also observed that iron and steel immersed for a time in dilute acids become brittle. He therefore concluded that hydrogen is absorbed in this case as in the former. Iron allowed to remain in dilute acids for five hours gained in weight in hydrochloric acid 0.028 per cent. and in sulphuric acid 0.036 per cent. When the iron which had been removed from the acid solution was heated, hydrogen was evolved, and the weight of the iron returned to a value very close to its former weight. When a stream of hydrogen was allowed to pass over the same iron, little or no hydrogen was absorbed, and the iron did not become brittle. Johnson therefore concluded that hydrogen must be in the nascent state in order to be occluded.

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[36] *Jour. of Iron and Steel Inst.*, 23, 1874–1875, pp. 168–180.

Hughes,[37] Baedeker,[38] and Ledebur[39] have all recorded the observation that iron, when attacked by dilute hydrochloric or sulphuric acids, occludes hydrogen.

Le Blanc,[40] in his researches on decomposition voltages, observed that the values of the decomposition voltages of many elements varied considerably when hydrogen was known to be evolved. In cases in which no hydrogen was evolved, the values of the decomposition voltages were found to be normal.

Roberts-Austen,[41] by galvanic precipitation of a chemically pure solution of ferrous sulphate, *produced a piece of iron, which evolved hydrogen when warmed in water at 70° C.* This evolution of gas ceased after several hours, however, and the iron was then heated in an evacuated porcelain tube, the temperatures being read by means of a Le Chatelier pyrometer. A further evolution of gas occurred, and it was noted that, no matter how long the sample was heated, gas continued to be liberated, although the amounts were very slight indeed by the time a temperature of 1300° C. was obtained. The sample of iron was heated to 1300° C. and allowed to cool several times in succession. The cooling curves were plotted, and it was observed that certain critical points at 261° and 481° C., which were at first present, gradually disappeared with repeated heatings. Roberts-Austen decided that these critical points were due to hydrogen occluded in the metal. The test piece of iron was then made the negative pole of a galvanic cell for a short time. The iron was heated again and the cooling curves plotted as before. It was observed that the upper critical point at 481° C. had been partially restored, but that the lower one was still absent. Roberts-Austen suggested that the upper point had been due to the presence of a hydride and that the lower point had been due to the formation of an eutectic.

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[37] *Jour. of Soc. of Telegraph Engin.*, 1880, p. 163.

[38] *Zeit. des Vereins deutscher Ingenieure*, 1880, p. 186.

[39] *Stahl u. Eisen*, 1887, p. 681; 1889, p. 74.

[40] *Zeit. fur physik. Chem.*, 12, 1893, pp. 333–358.

[41] *Proc. Inst. Mech. Eng.*, 1899, 5th Report Alloys Research Comm., pp. 42–74.

More recently T. W. Richards and G. E. Behr[12] observed that the electromotive force of iron varied with the amount of occluded hydrogen. In their experiments a porcelain tube heated with a Fletcher burner was used. Temperatures were measured with a platinum rhodium thermocouple according to the method of Le Chatelier. These investigators first experimented with iron reduced from iron oxide in a stream of hydrogen gas at 570° C. Iron prepared in this manner was found to possess an electromotive force considerably lower than the normal electromotive force of iron (0.795). Upon heating the iron, hydrogen was evolved, and thus the low electromotive force of the iron was accounted for, since the electromotive force of hydrogen is lower than that of iron. The investigators therefore concluded that the hydrogen was present in the same form as in pure hydrogen gas.

Certain experiments were conducted with the object of ascertaining what change, if any, occurs in the structure of iron when it is suddenly quenched. Test samples were heated to 700° C., allowed to fall through an atmosphere of hydrogen to prevent oxidation, and caught in cold water. Such samples possessed at first an electromotive force 0.15 volt higher than the electromotive force of ordinary iron. When allowed to stand in solutions of ferrous sulphate or of potassium sulphate, or in water, hydrogen bubbles were evolved and the electromotive force slowly receded to normal. This drop occurred most rapidly in the ferrous sulphate solution. Because the same results were obtained when the hot iron was allowed to fall through nitrogen instead of through hydrogen, the theory was advanced that the hydrogen occluded by the iron was formed by the decomposition of the water into which the hot iron fell. Iron serving as a cathode also exhibited this high initial electromotive force, but, on standing, gradually decreased to its normal value. Iron which had stood in a desiccator for one year showed no tendency to reduce potassium ferricyanide, whereas newly prepared iron reduced it at once. Iron heated for a time in hot hydrogen gas exhibited a slightly abnormal electromotive force.

From the results of the investigators described above, Richards and Behr concluded that the high electromotive force found in certain samples of iron was due to hydrogen occluded in the nascent form, it being immaterial whether the gas was prepared electrolytically or chemically. A small amount only of this active gas was present in hot hydrogen gas. The explanation offered by Richards and Behr for the variation in activity of the various kinds of hydrogen gas is that: ordinary hydrogen gas is molecular; occluded hydrogen gas has been dissociated and is therefore atomic without, however, being ionized.

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[12] *Zeit. für physik. Chem.*, **58**, 1907, pp. 335-349.

(To be continued.)

Effects of Storage upon the Properties of Coal. S. W. PARR. (Bulletin No. 97, *Engineering Experiment Station,* University of Illinois, May 28, 1917.)—Freshly-mined coal is chemically very active. Certain constituents have a marked affinity for oxygen, with which they enter into combination at ordinary temperatures. While the extent of this reaction depends upon the variety of the coal and the amount of these active constituents, a very important factor is the fineness of division or the sum-total of the superficial areas of the particles and accessibility of oxygen to the mass. There is an increase of "fines" or slack resulting from storage, greater with some coals than with others. This, together with the saturation of the free-burning constituent with oxygen, checks the fire and gives the appearance of a lack of heat value. However, with an increase of draft and a correct understanding of the combustion conditions to be maintained, a most excellent over-all efficiency can be secured, even from coals which have been in storage for long periods.

The actual loss in heat value resulting from storage is small. It is evident that upon mining out the coal from the bed certain volatile constituents are set free. The heat values represented by such exudations are not great. The tendency to absorb oxygen from the air is also a marked characteristic of freshly-mined coal. This is in reality a chemical process, and is accompanied by the generation of a small amount of heat, but these losses, compared with the total heat available in the coal, are insignificant.

Bituminous coal can be stocked without appreciable loss of heat values, provided the temperature is not allowed to rise above 180° F. Any method of storage, to be successful, must either check or prevent the absorption of oxygen to such an extent that the generation of heat shall not proceed faster than the dissipation and loss of heat due to absorption and radiation. Under-water storage prevents loss of heat values and is not accompanied by deterioration in physical properties, such as slacking. The water retained by the coal upon removal is substantially only that held by adhesion and capillarity. Dry storage is safer and more satisfactory if the fine material is screened out at the storage yard and lump only, preferably sized, is stocked.

The most serious part of the problem relates to the matter of spontaneous heating, and probably the least serious phase relates to deterioration and actual loss of heat values. It is certain that at the present time a better understanding of these difficulties has been reached, and there is reason for believing that this better understanding of the fundamental principles involved will lead to some practicable and safe procedure for the stocking of bituminous coal.

Geothermic Steam Generation. ANON. (*Scientific American*, vol. cxvii, No. 17, p. 305, October 27, 1917.)—The remarkable achievement of successfully utilizing underground volcanic heat for the generation of power in the neighborhood of Lardarello, Central Tuscany, Italy, naturally suggests the possibility of applying the same method in other localities. Such utilization of the internal heat of the earth, however, is dependent upon exceptional physical conditions, and it has occurred to an American engineer, Mr. Nathaniel B. Wales, that these conditions could be produced artificially. The increase in temperature of the earth's strata in proportion to its depth shows a mean average for the entire earth surface of one degree Fahrenheit for every 55 feet of depth. There are many regions, however, where this increase in temperature is far exceeded. Hundreds of areas are to be found in the United States where the temperature rises one degree for every 20 or 25 feet of depth. There is a locality near Boisé, Idaho, where three wells driven to only 400 feet yield 800,000 gallons of water daily at a temperature of 170°.

It is Mr. Wales's plan to sink a well-casing wherever the geothermic conditions are favorable until a stratum of high temperature, say 350° to 450° Fahrenheit or higher, is penetrated. Surrounding this shaft, a number of other casings would be sunk. Water would be injected into the heated stratum through the central well-casing, and the head of the water would cause it to percolate through the surrounding strata, from which it would absorb heat and be converted into steam. The steam then would rise through the circle of well-casings surrounding the central water shaft, and could be employed for power or heat. In this way a large zone embracing several acres could be utilized to form the active heating surface, drawing heat through the contiguous rock from an enormous radiant rock contact and allowing an inflow of heat from millions of tons of the earth's mass. The permanence of such an evaporative surface is amply proved by the maintenance of hot artesian wells, which are to be found throughout the world.

There are many areas in this country where borings not over 5000 feet would give the necessary temperature, and others of 1500 feet or less would supply all the heat required. In some places the steam generated might have to be used indirectly because of the earth's salts held in suspension; but no doubt these salts could very profitably be recovered and would add to the value of the installation.

PHYSICS OF THE AIR.*

BY

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CHAPTER XI.

BAROMETRIC FLUCTUATIONS.

THE pressure of the atmosphere undergoes changes that may be classified as seasonal, regional, storm, "ripple," diurnal, and semidiurnal. Most of these have already briefly been referred to, but they deserve further and separate consideration.

Seasonal Pressure Changes.—Since the atmosphere both expands and becomes more humid with increase of temperature, and when cooled contracts and also loses moisture, it follows that the resulting circulation, due to gravity, decreases the mass of air, and therefore its pressure, over places at or near sea level in any warming region and increases it, and its pressure, at similar levels over cooling regions. Hence, in general, the normal reading of the barometer at sea level is greater during winter than summer. It is not much greater, however—perhaps two or three millimetres on the average—since the viscosity of the atmosphere is too small to enable it to maintain any considerable pressure gradient. At places of high elevation the average actual (not reduced) pressure is *less* during winter than summer because of the increased density, during the colder season, of the lower air.

The approximate level at which January and July pressures, say, are equal may be computed as follows:

Let the sea-level pressures differ by 2.5 mm. and let the January temperature of the lower air be 20° C. colder than that of July. The pressure difference represents a stratum of the lower air about 27 metres thick, while the temperature difference is, roughly, 0.075 of the absolute temperature. Hence, under the above conditions, the height h at which the January and July pressures are the same is given approximately by the equation:

$$h = \frac{27 \text{ metres}}{0.075} = 360 \text{ metres.}$$

In addition to this seasonal pressure change over the whole of the northern and southern hemispheres, complicated to some extent by local conditions and the shifting of the belts of high pressure, there also are similar but greater pressure changes between the continents (high in winter, low in summer) and oceans (high in summer, low in winter) of each hemisphere itself. This pressure swing between continent and ocean is due to the fact that the summer temperature of the land is much higher and its winter temperature much lower than that of the water.

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* Continued from page 117, vol. 185, January, 1918.

Regional Pressure Changes.—The great semipermanent lows and highs often shift more or less from their normal positions. These displacements may be in any direction (more frequent in some than in others) and may last for any length of time, from a day or two to a fortnight or even longer. Such pressure changes, whatever their immediate cause, obviously are not seasonal, since they occur at all times of the year. Neither are they of the migratory storm type, though themselves contributing to the genesis and development of storms and of great importance in the control of storm courses.

Storm Pressure Changes.—The progressive travel of cyclones and anticyclones, or, rather, of cyclonic and anti-cyclonic conditions, necessarily implies a regular order of pressure changes, through a range often amounting to 25 mm. or more, at each point along the storm path. This type of change, frequent in extratropical regions at all times of the year, seldom lasts longer than 24 to 36 hours, and averages, perhaps, about 18 hours.

A secondary pressure change, due to the rapid rotation of a tornado or a waterspout, very intense but exceedingly brief—averaging less than one minute—occasionally develops under special conditions.

Perhaps, too, the pulsatory irregularities of the barometer during a thunderstorm should also be included here. Their origin, however, is entirely different.

Barometric "Ripples."—Small pressure changes, amplitude usually 0.1 mm. to 0.3 mm. and period of 5 minutes to 10 minutes, Fig. 54 (the regularly spaced vertical lines along the trace are hour marks), and continuing for hours or even days together, are very common during cold weather. As first demonstrated by Helmholtz,[60] whenever layers of air that differ in density at their interface flow over each other long billows, analogous to gravity water waves, are produced which conform approximately to the equation,

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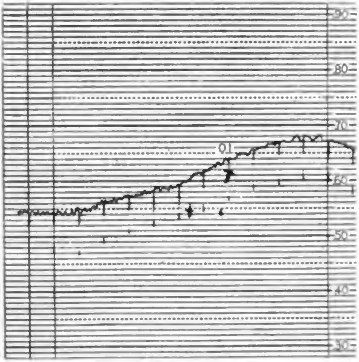
[60] *Sitz. der K. P. Akad. Berlin*, 1889, p. 761; 1890, p. 853. Translated by Cleveland Abbe, "Mechanics of the Earth's Atmosphere," Smithsonian Institution, 1891.

$$d_1(u-V)^2 + d_2(V-v)^2 = \frac{g\lambda(d_2-d_1)}{2\pi}$$

in which V is the velocity of wave propagation, d_1 and d_2 the densities of the layers whose velocities are u and v, respectively, g the gravity acceleration, and λ the wave-length. If, now, the under layer is colder than the upper, as often happens during winter, and rather shallow, 100 metres to 500 metres thick, say, the passage of the air billows, like the passage of waves in shallow water, necessarily produces greater or less corresponding changes in the pressure on the bottom—changes that appear as a series of ripples in the record of a sensitive barograph. Furthermore, such shallow air billows, like shallow water waves, doubtless are turbulent—a condition that accounts, presumably, for the surprisingly rough flying the aviator often experiences during winter at low levels—300 metres and less.

FIG. 54.

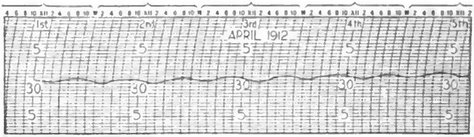


Barometric ripples.

During summer, when air billows rarely form near the surface, though frequently at greater altitudes, especially that of the cirrus cloud, neither barometric ripples nor shallow turbulences of the kind just mentioned often occur. This, doubtless, is because wave disturbances in air as in water do not penetrate far beneath the wave level.

Diurnal and Semidiurnal Pressure Changes.—It has been known now for two and a half centuries that there are more or less regular daily variations in the height of the barometer, culminating in two maxima and two minima during the course of 24 hours. The phenomenon in question is well illustrated by Fig. 55, a direct copy of a barograph trace obtained April 1–5, 1912, on Grand Turk Island, latitude 21° 21′ N., longitude 70° 7′ W. It is further illustrated, and shown to persist through all the seasons, by Fig. 56, which gives, from hourly values, the actual average daily pressure curve for each month, and also for the entire year, as observed at Key West, latitude 24° 33′ N., longitude 81° 48′ W., during the 14 years, 1891–1904. The actual values are given in the accompanying table.

FIG. 55.



Barogram, Grand Turk Island, West Indies.

Probably the earliest observations of these rhythmical daily changes in the atmospheric pressure were made by Doctor Beal [61] during the years 1664–65, and therefore very soon after the invention, 1643, of the mercurial barometer. Since Beal's discovery the same observation has been made and puzzled over at every station at which pressure records were kept and studied, but without success in finding for it any adequate physical explanation. In speaking of the diurnal and semidiurnal variations of the barometer, Lord Rayleigh [62] says:

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[61] *Phil. Trans.*, 9 (1666), p. 153.

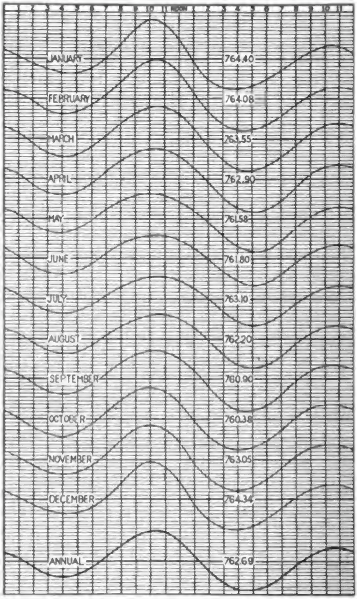
[62] *Phil. Mag.*, 29 (1890), p. 179.

Average Hourly Readings of the Barometer, 1891–1904, at Key West, Latitude 24° 33′ N., Longitude 81° 48′ W., Elevation. 7 Metres.

75th Meridian time	January	February	March	April	May	June	July	August	September	October	November	December	Year
Average	764.40	764.08	763.55	762.90	761.58	761.80	763.10	762.20	760.90	760.38	763.05	764.34	762.69
1 A.M.	+.07	+.15	+.17	+.15	+.12	+.02	+.12	+.15	+.14	+.02	+.05	+.05	+.10
2 A.M.	−.11	−.05	−.10	−.14	−.14	−.20	−.14	−.10	−.10	−.21	−.16	−.11	−.13
3 A.M.	−.27	−.30	−.38	−.39	−.34	−.38	−.34	−.30	−.35	−.39	−.34	−.31	−.34
4 A.M.	−.37	−.41	−.48	−.45	−.37	−.41	−.39	−.40	−.42	−.46	−.39	−.38	−.41
5 A.M.	−.39	−.38	−.43	−.34	−.29	−.34	−.34	−.35	−.35	−.34	−.36	−.38	−.36
6 A.M.	−.29	−.20	−.20	−.11	−.06	−.13	−.19	−.15	−.15	−.13	−.16	−.26	−.15
7 A.M.	+.02	+.13	+.12	+.25	+.27	+.17	+.10	+.15	+.19	+.20	+.17	+.08	+.15
8 A.M.	+.40	+.46	+.31	×.50	+.50	+.45	+.32	+.34	+.44	+.50	+.52	+.43	+.43
9 A.M.	+.83	+.82	+.74	+.72	+.65	+.58	+.50	+.54	+.67	+.78	+.83	+.84	+.71
10 A.M.	+1.10	+1.05	+.87	+.82	+.70	+.63	+.57	+.66	+.80	+.88	+.96	+1.04	+.83
11 A.M.	+.98	+1.05	+.89	+.82	+.67	+.65	+.62	+.69	+.77	+.78	+.83	+.81	+.81
Noon	+.54	+.71	+.68	+.62	+.55	+.55	+.52	+.56	+.56	+.42	+.45	+.50	+.56
1 P.M.	−.08	+.18	+.23	+.32	+.29	+.30	+.30	+.31	+.24	−.05	−.11	−.16	+.15
2 P.M.	−.57	−.33	−.20	−.06	−.06	+.00	+.05	−.02	−.20	−.46	−.51	−.59	−.26
3 P.M.	−.80	−.68	−.56	−.50	−.44	−.33	−.31	−.40	−.60	−.72	−.77	−.77	−.56
4 P.M.	−.83	−.86	−.84	−.80	−.75	−.59	−.59	−.71	−.86	−.85	−.87	−.84	−.79
5 P.M.	−.73	−.83	−.89	−.90	−.88	−.74	−.72	−.79	−.86	−.77	−.75	−.74	−.79
6 P.M.	−.57	−.71	−.76	−.85	−.85	−.69	−.65	−.71	−.71	−.59	−.54	−.53	−.69
7 P.M.	−.34	−.48	−.50	−.60	−.60	−.41	−.41	−.45	−.42	−.31	−.26	−.26	−.41
8 P.M.	−.01	−.15	−.18	−.21	−.22	−.08	−.11	−.12	−.05	+.07	+.10	+.05	−.08
9 P.M.	+.19	+.10	+.12	+.12	+.04	+.15	+.12	+.15	+.24	+.32	+.30	+.28	+.17
10 P.M.	+.32	+.26	+.36	+.32	+.27	+.33	+.30	+.34	+.39	+.42	+.40	+.38	+.36
11 P.M.	+.32	+.34	+.41	+.37	+.34	+.40	+.35	+.39	+.39	+.40	+.40	+.38	+.38
Midnight	+.22	+.26	+.33	+.30	+.27	+.30	+.30	+.28	+.29	+.25	+.25	+.23	+.27

"The relative magnitude of the latter [semidiurnal variation], as observed at most parts of the earth's surface, is still a mystery, all the attempted explanations being illusory."

FIG. 56.

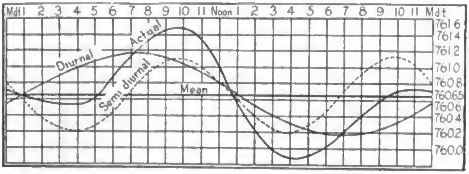


Average daily barometric curves, Key West, Florida.

Obviously the average hourly pressures for a decade or longer at any given place are practically free from storm and other irregular effects, but contain all diurnal and shorter period disturbances that may exist. On being analyzed these actual data show two well-defined sine curves, a diurnal and a semidiurnal, as illustrated by Fig. 57,[63] each of which requires a special explanation. Higher harmonics of very small amplitude have also been found, but, as neither the diurnal nor the semidiurnal disturbances can have true sine values throughout, it follows that the higher harmonics indicated by this type of analysis may not represent any actual force of the same periodicity.

Diurnal Pressure Changes.—There are two classes of well-defined 24-hour pressure changes. One obtains at places of considerable elevation and is marked by a barometric maximum during the warmest hours and minimum during the coldest. The other applies to low, especially sea level, stations and is the reverse of the above, the maximum occurring during the coldest hours and the minimum during the warmest.

FIG. 57.



Average daily barometric curve and its components, Washington, D. C. (After W. J. Bennett.)

The first class of changes just mentioned, the one that concerns elevated stations, is due essentially to volume expansion and contraction of the atmosphere caused by heating and cooling respectively. Thus the lower atmosphere over that side of the earth which is exposed to insolation becomes more or less heated, and therefore, because of the resulting expansion, its centre of mass is correspondingly raised. Conversely, during the night the atmosphere cools and contracts and the centre of mass is proportionately lowered. Hence, so far as this effect alone is concerned, a mountain station, 1000 metres, say, above sea level, will have the greatest mass of air above it when the atmosphere below is warmest or most expanded, and the least when the lower atmosphere is coldest or most contracted—that is to say, this effect tends to produce, at such stations, barometric maxima during afternoons and minima about dawn.

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[63] Bennett, *Monthly Weather Review*, 34 (1906), p. 528.

There is, however, another effect resulting from the volume expansion and contraction of the atmosphere to consider; namely, its lateral flow. To this, mainly, is due that daily barometric swing at sea level, as shown by harmonic analysis, the early evening minimum and the early morning maximum, that is the reverse of the high-level oscillation.

The expansion and consequent vertical rise of the air on the warming side of the earth, together with the simultaneous contraction and fall of the atmosphere on the cooling side, establishes a pressure gradient at *all* levels of the atmosphere directed from the warmer toward the cooler regions, a gradient that obviously causes the well-known heliotropic wind—the wind that turns with the sun—and thus leads to maximum pressures at the coldest places and minimum pressures at the warmest. But as these regions are along meridians, roughly, 10 hours, or 150 degrees apart, and perpetually move around the earth at the rate of one revolution every 24 hours, there must be a corresponding perpetual flow of air, or change of flow, as above described, in a ceaseless effort to establish an equilibrium which, since the disturbance is continuous, can never be attained.

Semidiurnal Pressure Changes.—Both the actual barometric records and their harmonic analyses show conspicuous 12-hour cyclic changes that culminate in maxima and minima at approximately 10 o'clock, A.M. and P.M., and 4 o'clock, also both A.M. and P.M., respectively—the exact hour in each case depending somewhat upon season, elevation, and, presumably, weather conditions.

Some of the observed facts in regard to this 12-hour cyclic change of pressure are:[64]

(*a*) The amplitude is greatest in the tropics and decreases toward the poles, approximately as the square of the cosine of the latitude.

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[64] Angot, "Étude sur la marche diurne du baromètre," *Annales du Bureau Central Météorol.*, 1887.

Hann, "Untersuchungen über die tägliche Oscillation des Barometers" *Denkschriften der Wiener Akademie*, Bd. 55, 1889.

Hann, *Meteorol Zeit.*, 15 (1898), 361.

(*b*) The amplitude is everywhere greatest on equinoxes and everywhere least on solstices.

(*c*) The amplitude is greater at perihelion than at aphelion.

(*d*) The amplitude is greater by day than by night.

(*e*) The amplitude is greatest on clear days and least on cloudy.

(*f*) The day amplitude is greater over land than over water.

(*g*) The night amplitude is greater over oceans than over continents.

(*h*) Over the tropical Pacific Ocean the forenoon barometric maximum is about 1 mm. above and the afternoon minimum 1 mm. below the general average pressure.

Obviously, other things being equal, both the daily change in temperature and the resulting change in convection are greater in the tropics than elsewhere; greater at perihelion than at aphelion; greater during clear weather than cloudy; greater over land than over water; and greatest when the time of heating and the time of cooling (day and night) are equal, and least when these are most unequal or at the times of solstice. Hence all the above facts of observation strongly favor, if they do not compel, the conclusion that the daily cyclic pressure changes are somehow results of daily temperature changes. There are, however, a number of other causes of slight pressure changes,[65] but apparently only the following have any appreciable value:

1. *Horizontal flow of the atmosphere from the regions where it is most expanded toward those where it is most contracted.*

The exact hour at which the atmosphere is warmest and most expanded depends upon a variety of circumstances, but on the average it is approximately at 4 o'clock in the afternoon. Hence, in general, at about this time the amount of air overhead, counting from sea level, should be least, and therefore at this hour a sea-level barometer should have its lowest reading. On the other hand, lowest temperatures and maximum contractions obtain soon after dawn, or shortly before 6 A.M. throughout the year near the equator, and everywhere at the time of equinox.

The 24-hour swing of the barometer, therefore, does not appear to be of even period, but rather of intervals that are to each other, roughly, as 5 to 7. To be sure, the barometer is lower at 6 o'clock in the afternoon than at the same hour of the morning, and hence one may assume an even period 24-hour swing, with a morning 6 o'clock maximum and evening 6 o'clock minimum, and partially correct this regular curve (the correction is never perfect) by the superposition of one or more additional sine curves of convenient periods. But this approximation to the true curve does not prove the existence of actual forces with the periods assumed.

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[65] Humphreys, *Bul. Mt. Weather Obsy.*, 5 (1912), p. 132.

It appears, then, that the physical causes of the 24-hour component of the diurnal pressure changes are such as to give a morning maximum at about 6 o'clock and an afternoon minimum at about 4 o'clock. The above causes of pressure change, however, do not account for either of the 10 o'clock maxima.

2. *Interference by vertical convection with free horizontal flow.*

It was long ago suggested by Abbe[66] that convectional interference is the principal cause of the forenoon maximum pressure, which indeed it probably is, as the following consideration shows:

Let the mass m of air be near the ground and have the horizontal velocity v, and let the larger mass M be at a higher elevation and have the greater velocity V in the same direction. If now these two masses should mingle in such manner as to be free from all disturbance, except their own mutual interference, the resulting final velocity, U, in the same direction, would be given by the equation—

$$U = \frac{mv + MV}{m + M}$$

and there obviously would be no check in the total flow—no damming up and consequent increase of pressure. But this simple mixing of the two masses is by no means all that happens in the case of vertical convection. The rise of the mass m is simultaneously accompanied by an equivalent descent of air from a higher level, which in turn loses velocity, directly or indirectly, by surface friction. If the falling mass is also m, and if its velocity is reduced by friction to v, then from a single interchange, due to vertical convection, the total momentum becomes—

$$2\,mv + (M - m)\,V$$

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[66] "Preparatory Studies" (1890), pp. 8 and 56.

and the total flow is reduced by the amount

$$m\,(V-v)$$

But as this is for a single interchange, it is obvious that the more active vertical convection becomes, the greater will be its interference with the flow of the atmosphere, the more the winds will be dammed up, and the higher the barometric pressure. As convection increases, reaches a maximum, and then decreases, so, too, will the resulting interference go through the same changes.

Now the general movement of the atmosphere is from east to west within the tropics and from west to east at higher latitudes. Therefore in either case such damming up of the air as vertical convection may produce will be essentially along meridians, and thus a function of the time of day. But, in general, convection increases most rapidly during the forenoon, say 8 to 9 o'clock, is most active at 10 to 11 o'clock, and reaches its greatest elevation about 4 o'clock in the afternoon. Hence the damming up of the atmosphere, due to vertical convection, and the resulting increase of barometric pressure must increase most rapidly during the forenoon, and come to a maximum about 10 o'clock. After this the convectional interference decreases, while at the same time the amount of air in a vertical column of fixed cross-section decreases as a result of expansion and overflow, until at about 4 o'clock in the afternoon the barometric pressure, as already explained, has reached a minimum.

To form some idea of the magnitude of the barometric change due to convectional turbulence, consider the atmosphere between two parallels of latitude near the equator. This limited quantity may be regarded as a stream flowing around the earth, having its minimum velocity and maximum depth where convectional interference is greatest, and maximum velocity with minimum depth where convection is absent. And since the linear velocity of a point on the equator is approximately 28 kilometres per minute, while during the forenoon the rate of increase of the barometric pressure at the same place is, roughly, 0.2 mm. per hour, it follows that a damming up, or check in the flow, of the given stream at the rate of 0.44 kilometre per hour would be sufficient of itself to account for the observed rise in the barometer. But if the average velocity of the wind, or flow of the stream in question, is 10 metres per second, which it may well be, the rate of decrease in velocity requisite for the given rate of pressure increase could be produced by having only 1 part in 80 of the whole superincumbent atmosphere brought to rest per hour, or the equivalent thereof, an amount that perhaps is reasonable. At any rate, the assumed velocity decrease is of the same order of magnitude as that observed to take place during, and as the result of, diurnal convection.

Summing up the effects of all the above causes of barometric changes, it appears:

(*a*) That the afternoon minimum is caused essentially by overflow from the region where the atmosphere is warmest, or better, perhaps, from the meridian along which the temperature increase has been greatest, toward that meridian along which there has been the greatest decrease in temperature.

(*b*) That vertical convection interferes with the free horizontal flow of the atmosphere and to that extent dams it up and correspondingly increases the barometric pressure; also, that the time of this interference agrees with the forenoon changes of the barometer, and that its magnitude is of about the proper order to account for the forenoon barometric maximum.

The afternoon barometric minimum and the forenoon maximum, therefore, are to be regarded as effects of temperature increase; the minimum as due to expansion and consequent overflow; the maximum as caused by vertical convection and consequent interference with the free circulation of the atmosphere.

The forced afternoon minimum would occur in an otherwise stagnant atmosphere, and substantially as at present; but not so with the forced forenoon maximum, since the interference or damming effect depends upon a flow or circulation of the atmosphere, parallel roughly to the equator.

It remains now to account for the night 10 o'clock maximum and 4 o'clock minimum.

3. *Natural or free vibration of the atmosphere as a whole.*

This subject has been discussed by several mathematical physicists of great eminence. The latest and most complete of these discussions, and the one to which those interested in this phase of the barometric problem are especially referred, is by Lamb,[67] who concludes:

"Without pressing too far conclusions based on the hypothesis of an atmosphere uniform over the earth, and approximately in convective equilibrium, we may, I think, at least assert the existence of a free oscillation of the earth's atmosphere, of 'semi-diurnal' type, with a period not very different from, but probably somewhat less than, 12 mean solar hours."

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[67] *Proc. Roy. Soc.*, A. **84** (1911), p. 551.

Hence any cause of pressure change, having a semidiurnal period or approximately so, would, if of sufficient magnitude and proper phase, account for the 12-hour barometric curve. Such a cause, many think, may be found in the irregular daily march of temperature, since the curve expressing this march is more or less approximately resolvable into a diurnal and a semidurnal sine curve. But the resolution is not perfect and, besides, there is no obvious cause for a temperature increase by night, and hence the reality of the semidurnal component in the temperature curve is equally doubtful.

All that is needed, apparently, to give the semidiurnal pressure curve is a pressure impulse of the same period, 12 hours, as that of the free vibration of the atmosphere as a whole. And this is furnished by the forced forenoon barometric maximum, followed six hours later at the same place by the forced afternoon barometric minimum. In other words, taken altogether, the forenoon and afternoon forced disturbances appear to occur with the proper time interval necessary to set up and maintain the 12-hour free vibrations of the atmosphere.

The course of events at each locality appears to be substantially as follows:

1. A forced forenoon compression of the atmosphere, followed by its equally forced afternoon expansion, the two together forming one complete barometric wave, with a 10 o'clock maximum and a 4 o'clock minimum, in harmony with the free vibration of the entire atmospheric shell.
2. Nondisturbance through the night or during the time of a single free vibration.
3. Repetition the following day of the forced disturbances in synchronism with, and therefore at such time as to reënforce, the free vibrations.

The series of disturbances is continuous, forced by day and free by night, but the resulting amplitudes of the barometric changes are limited, through friction and through the absence of perfect synchronism, to comparatively small values. Each point upon the atmospheric shell receives at every alternate swing a forced impulse in phase with the free vibration, and therefore at such time and in such manner as indefinitely to maintain the vibrations of the atmosphere as a whole.

The forenoon maximum and the afternoon minimum are primary disturbances equally forced but in different ways by the daily increase of temperature, while the evening maximum and the morning minimum are secondary disturbances caused by the joint action of the forced primaries through the 12-hour free vibration of the atmosphere. In short, the semidiurnal swing of the barometer is a result of merely fortuitous circumstances—of the fact that the mass of the atmosphere happens to be such that the period of its free vibration is approximately just one-half that of the earth's rotation.

(To be continued.)

Power Transmission Through Separating Diaphragms. ANON. (*Electrical World*, vol. 70, No. 25, p. 1188, December 22. 1917.)—The invention of Benjamin Graemiger, of Zurich, Switzerland, patent No. 1,233,569, relates to apparatus for driving machines by means of purely magnetic forces, such that the driving and driven members are separated from each other in a gas-tight manner without the provision of a stuffing box by a partition or wall. Accordingly metal alloy of great strength and which is a very bad electrical conductor is employed for the separating partition between the driving end and driven members. The power-driven machine inclosed in a casing is driven, for instance, from the exterior without involving the use of a stuffing box by inclosing the rotor of an electromotor of any suitable construction coupled to the shaft of the machine in the casing and by separating the driving member—that is to say, the stator of the motor—in a gas-tight manner from the rotor by a wall or partition forming a part of the casing.

On the shaft driven by a prime mover is keyed the driving member, consisting of two disks between which is arranged the winding required for excitation purposes. The two disks have cylindrical polar surfaces arranged facing each other and formed with projections. The driven member is keyed on a shaft of the machine to be driven and consists of a bell-shaped disk, the cylindrical portion of which extends between the two polar surfaces of the driving member and is also formed with projections on the inside and the outside. The separating partition arranged between the two members is in the form of a ring of U-section and is connected in a gas-tight manner to the parts of the casing. The action of the drive is due to the magnetic flux lines generated by the energizing winding.

OUTLINE OF COLLOID CHEMISTRY.—III.*

BY

WILDER D. BANCROFT.

PREPARATION OF COLLOIDAL SOLUTIONS.

Types of Precipitates.

IT has been shown that sufficiently finely divided particles will be kept in suspension in a liquid indefinitely by the Brownian movements, provided coalescence and the resulting agglomeration are prevented. A stable colloidal solution will therefore consist of very fine particles kept from agglomerating by a protecting film[1] of some sort, electrification being equivalent to a film.[2] Small particles[3] may be obtained either by condensation from vapor or solution (usually called precipitation) or by disintegration of larger masses. The disintegration is often called peptization, especially when done chemically, as opposed to mechanical or electrical disintegration. It seems desirable to distinguish eight types of precipitates: crystalline; colloidal or non-settling; flocculent; curdy; sandy; gelatinous; jelly-like; fluid. A crystalline precipitate is one that is distinctly crystalline and settles rapidly, as when KOH is neutralized by H_2SO_4 or when moderately concentrated solutions of lead nitrate and potassium chromate are mixed. A non-settling precipitate may be anhydrous or hydrous; there is little or no agglomeration. A typical case is the precipitation of lead chromate from very dilute solutions of lead nitrate and potassium chromate. A flocculent precipitate is obtained when a non-settling, non-gelatinous precipitate agglomerates to a bulky mass. It is easy to obtain a flocculent precipitate of silver chloride from suitable solutions of silver nitrate and potassium chloride. Haber and Oordt[4] call the precipitate of beryllium hydroxide flocculent; but I am not certain whether they are limiting the term sufficiently sharply. A curdy precipitate is obtained when a flocculent precipitate agglomerates to a fairly dense mass. The typical case is, of course, the precipitation of caseine by acids, but a similar precipitate can be obtained with $AgNO_3$ and HCl. There is no sharp dividing line between a flocculent and a curdy precipitate. A sandy precipitate is obtained when a flocculent or a curdy precipitate agglomerates to a dense mass. The alumina obtained from hot sodium aluminate in the Bayer process is a sandy precipitate.[5] A granular or sandy alumina is said to be precipitated by ammonia[6] at 66°. A gelatinous precipitate is always hydrous and viscous; it involves agglomeration to a bulky form. Hydrous alumina and hydrous ferric oxide, when precipitated cold, are typical gelatinous precipitates. When a salt is precipitated from very concentrated solutions we apparently always get a gelatinous precipitate. Thus gelatinous barium sulphate is obtained by mixing concentrated solutions of barium sulphocyanate and manganous sulphate,[7] and gelatinous calcium carbonate by mixing concentrated solutions of calcium chloride and sodium carbonate. The difference between a gelatinous precipitate and a jelly is that the liquid phase is visible as such in the case of the gelatinous precipitate and is not in the case of the jelly. A jelly is always hydrous, viscous, and bulky; it may consist of a number of coalescing drops or rods, in which case both phases are continuous; or it may consist of coalescing films, in which case we have a honeycomb structure, with water as the internal phase. A typical jelly can be obtained with sodium silicate and hydrochloric acid. A fluid precipitate is one which is too mobile to be classed as a gelatinous precipitate. Sodium phenolate or sodium oleate with an excess of HCl gives a fluid precipitate.

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* Based on a paper presented at a meeting of the Section of Physics and Chemistry, held Thursday, January 11, 1917.

[1] Cf. Höber: *Physikalische Chemie der Zelle und der Gewebe*, 233. (1914).

[2] Cf. Hardy: *Proc. Roy. Soc.*, **86 A**, 601 (1912).

[3] Freundlich: "*Kapillarchemie*," 527 (1909).

[4] *Zeit. anorg. Chem.*, **38**, 377 (1904).

The mean mass of the crystals in a crystalline precipitate is given by the total weight of the precipitate divided by the number of crystals. Experimentally we find that the number of nuclei increases less rapidly than the concentration at first and more rapidly later. When very dilute solutions are mixed, the number of nuclei is so large relatively to the weight of the precipitate that the particles themselves are very small. With increasing concentration we get increasing size of crystals for a while and then decreasing size, because the number of nuclei then increases more rapidly than the concentration. At very high concentrations a gelatinous precipitate is always obtained, as has been pointed out. It is possible that we have here the appearance of a viscous and instable second liquid layer; but this has not yet been proved. At the Urbana meeting of the American Chemical Society, Clowes pointed out that a jelly is formed when a hydrous, viscous phase separates slowly in presence of a substance which tends to keep it dispersed.[8] To obtain large crystals one must have a solution so slightly saturated that no nuclei form spontaneously and that no branched crystals form in presence of a single crystal.[9] Von Weimarn[10] cites the case of a spring in which crystals of barium sulphate had grown 5 cm. long. It is easier to avoid excessive supersaturation when the substance is more soluble. Thus one can get crystals of silver chloride without trouble by dissolving the salt in ammonia.[11] The effect of other substances in the solution depends on their effect on the supersaturation and on whether they are adsorbed by the precipitate. This has been discussed fully for the case of barium sulphate by Weiser.[12] The question has been raised whether the finest precipitates are crystalline or amorphous. Von Weimarn[13] considers them all crystalline; but he considers that liquids and gases are crystalline, which throws him out of court, because he is not using the word in the same sense as other people. A supercooled liquid like glass is amorphous in the ordinary sense of the term. Whether a precipitate is amorphous or not is therefore a question whether it is a supercooled liquid or not. Von Weimarn is undoubtedly right in saying that many precipitates are really crystalline, though they are classed as amorphous; but there is no question that there are amorphous precipitates.

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[5] Russ: *Zeit. anorg. Chem.*, **41**, 216 (1904).

[6] Taylor *Chem. News*, **103**, 169 (1911).

[7] Von Weimarn: "Gründzüge der Dispersoidchemie," 67 (1911).

At higher temperatures precipitates are less hydrous and tend to be more coarsely crystalline. When barium sulphate is precipitated hot it does not run through the filter so readily as when precipitated cold. Other conditions being the same, a non-settling precipitate of silver[14] is obtained by reduction with hydrazine at 16° and pulverulent silver by reduction at 80° to 90°.

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[8] Cf. Hardy: *Jour. Physiology*, **24**, 167 (1899); *Proc. Roy. Soc.*, **66**, 95 (1900); **87 A**, 29 (1912).

[9] Cf. Hopkins: *Am. Chem. Jour.*, **25**, 413 (1907).

[10] "Grundzüge der Dispersoidchemie," 55 (1911).

[11] Reinders: *Zeit. phys. Chem.*, **77**, 696 (1911).

[12] *Jour. Phys. Chem.*, **21**, 314 (1917).

[13] *Zeit. Kolloidchemie*, **3**, 166 (1908).

Theory of Peptization.

We find experimentally that certain solutions will peptize or disintegrate certain precipitates so that we get colloidal solutions. This is always the result of adsorption. Theoretically there are three possibilities. If an adsorbed film has a low surface tension on the water side and a high one on the other side, it will tend to scrunch up and to peptize the solid as internal phase. If the reverse is the case, the solid will tend to form the external phase. If the two surface tensions are practically equal, neither will prevail. Some adsorbed substances seem to have practically no peptizing action;[15] but these cases should be studied again in the light of what we now know about colloid chemistry. If we adopt Freundlich's view that adsorption always lowers the surface tension, a theory of peptization follows at once.[16] We may have peptization by a liquid, by a non-electrolyte, by an adsorbed ion, by a salt, or by a peptized colloid. When a liquid is adsorbed by a solid, it will tend to peptize it and in some cases will do so. Water peptizes tannin, amyl acetate peptizes pyroxylin, and fused baths peptize metals. At higher temperatures the peptizing action increases, and we may get glass peptized by water[17] or vulcanized rubber by various organic liquids.[18] Gelatine is not peptized by cold water, but is by warm water. A concentrated solution of sugar in water will prevent the precipitation of calcium silicate, silver chromate, and silver chloride; also of lime and the hydrous oxides of copper and iron. There are a number of cases where mixed solvents will peptize a solid much better than either alone: cellulose nitrate in ether and alcohol, caseine in pyridine and water,[19] and probably cinchonine in chloroform and alcohol,[20] and also phloretine in ether and water.[21] The theory of this has not been worked out. Cellulose nitrate swells in alcohol and not in ether;[22] but it is not known whether this is universal or whether alcohol peptizes cellulose nitrate at higher temperatures. Zein is also peptized in mixed solvents.[23]

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[14] Gutbier: *Zeit. Kolloidchemie*, **4**, 308 (1909).

[15] Doyle: *Jour. Phys. Chem.*, **17**, 390 (1913).

[16] Bancroft: *Jour. Phys. Chem.*, **20**, 85 (1916).

[17] Barus: *Am. Jour. Sci.* (3), **38**, 408 (1889): **41**, 110 (1891); (4) **6**, 270 (1898); **7**, 1 (1899; *Phil. Mag.* (5), **47**, 104, 461 (1899).

[18] Barus: *Am. Jour. Sci.* (3), **42**, 359 (1891).

[19] Levites: *Zeit. Kolloidchemie*, **8**, 4 (1911).

[20] Oudemanns: *Jour. Chem. Soc.*, **26**, 533 (1873).

[21] Schiff: *Zeit. Phys. Chem.*, **23**, 355 (1897).

Freshly precipitated silver chloride is peptized by $AgNO_3$ or KBr, the silver and the bromine ions being adsorbed strongly. Many oxides are peptized by their chlorides or nitrates, forming so-called basic salts. Sulphides are peptized by hydrogen sulphide.[24] Gelatine is liquefied or peptized by a potassium iodide solution. There are no cases where it has been shown conclusively that peptization is due chiefly to adsorption of unadsorbed salt, but undoubtedly such instances will be found. Water-peptizable colloids like gelatine, dextrine, soap, or saponin will peptize many precipitates, and they are often called protecting colloids, because they prevent the agglomeration and settling of finely divided precipitates. Caseine is not peptized by water, but is peptized by acids and alkalies, and then acts as a protecting colloid. Hydrous chromic oxide is peptized by caustic potash and can then prevent the precipitation of hydrous ferric oxide, etc. If too much ferric oxide is present, all the chromic oxide is carried down by it.[25]

Since a colloidal solution is one in which we have a finely divided phase which is kept from coalescing in some way, it is clear that we may theoretically have as many colloidal alumina solutions as we please, varying all the way from anhydrous alumina (Al_2O_3) up to the most highly hydrous form that can be obtained. As a matter of fact, people have generally been satisfied with distinguishing only two sets of solutions, which they have called solutions of alumina and metalumina, stannic and metastannic acids, etc.[26] The theory of mechanical and electrical disintegration or peptization is so simple that it does not need to be discussed here, and it will be referred to when discussing the details of methods of preparing colloidal solutions. These methods are grouped under two main heads, the condensation methods and the dispersion methods. The condensation methods are to be discussed first.

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[22] Private communication from Professor Chamot.

[23] Galeotto and Giampalmo: *Zeit. Kolloidchemie*, **3**, 118 (1908).

[24] Young: *Jour. Phys. Chem.*, **21**, 1, 14 (1917).

[25] Northcote and Church: *Jour. Chem. Soc.*, **6**, 54 (1854); Nagel: *Jour. Phys. Chem.*, **19**, 331 (1915).

[26] Hautzsch: *Zeit. anorg. Chem.*, **30**, 338 (1902); Bancroft: *Jour. Phys. Chem.*, **19**, 232 (1915).

Condensation Methods.

In condensation methods we must have strong adsorption (including protecting colloids), or we must keep down the concentration of agglomerating agents either by choice of reagents or by dilution. A few instances will be given of the preparation of colloidal solutions in the presence of a strongly adsorbed substance. Colloidal palladium may be obtained by reduction with hydrazine in presence of gum arabic.[28] Colloidal solutions of silver chloride, silver bromide, or Prussian blue may be obtained by precipitation in presence of gelatine.[29] Sulphide solutions may be stabilized by gum arabic[30] or by sodium sulphide, but not by ammonium sulphide.[31] Silver chromate, hydrous copper oxide,[32] and hydrous ferric oxide may be obtained colloidal in presence of sugar.[33] Invert sugar holds up about seven times as much iron as cane sugar. Glycerin also enables us to make a colloidal solution of ferric oxide.[34] Gengou[35] prepared colloidal alumina and barium sulphate in presence of sodium citrate, and Schiaparelli[36] held up lead sulphide with saponin. A solution obtained by adding sulphuric acid to barium arabinate was milky after standing four years.[37] Cadmium sulphide can be obtained colloidal in presence of caseine,[38] and so can copper oxide,[39] while mercurous chloride can be held up by albumin.[40] All the metals and many other substances can be kept in colloidal solution by sodium protalbinate and lysalbinate, which are salts of somewhat

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[27] Svedberg: "Die Methoden zur Herstellung kolloider Lösungen anorganischer Stoffe."

[28] Svedberg, 105.

[29] Svedberg. 323.

[30] Lefort and Thibault: *Jour. Chem. Soc.*, **42**, 1322 (1882).

[31] Haussmann: *Zeit. anorg. Chem.*, **40**, 121 (1904).

[32] Svedberg, 224, 304.

[33] Riffard: *Jour. Chem. Soc.*, **27**, 292 (1874).

[34] Grimaux: *Ibid.*, **46**, 96 (1884).

[35] *Zeit. Kolloidchemie*, **9**, 88 (1911).

[36] *Jour. Chem. Soc.*, **46**, 332 (1884).

[37] *Ibid.*, **30**, 538 (1876).

[38] Svedberg, 325.

[39] Ritthausen: *Jour. Prakt. Chem.* (2), **5**, 215 (1873); **7**, 361 (1874).

[40] Svedberg, 325.

hypothetical acids obtained by saponification of albumin.[41] It is an open question whether they are any more effective than gelatine. Colloidal solutions of silver in organic solvents can be obtained with wool-fat as protecting colloid.[42] Carey Lea prepared colloidal silver of various colors by reduction of a silver salt with ferrous citrate or tartrate.[43] Both red and blue copper solutions have been obtained in presence of lysalbinates.[44] Colloidal gold and silver can be kept from coagulating by means of starch.[45] Mercury and bismuth may be kept up by stannic oxide[46] and gold by ceria,[47] while sodium sulphate keeps up sulphur in strongly acid solution and potassium sulphate precipitates it.[48] Acheson aquadag is kept in colloidal solution by tannin and iron oxide.[49]

In a number of other cases the agglomerating agent is kept low either by selection of the reaction or by dilution. Since electrolytes are very effective in producing precipitation in many cases, this usually means keeping the concentration of electrolytes very low. It may make matters clearer to classify the methods according to the type of reaction involved.

1. *Reduction without Electrolysis.*—At 50° hydrogen gas reacts slowly with silver oxide in presence of water, the dissolved silver oxide being the substance which reacts. The reaction is $Ag_2O + H_2 = 2Ag + H_2O$, so the silver is formed in the absence of electrolytes and tends to come down colloidal, though some does precipitate as a mirror.[50] From dilute solutions of gold salts, colloidal gold can be obtained by reduction with carbon monoxide, sulphur dioxide, formaldehyde, pinene, alcohol, hydrazine, and phenyl hydrazine.[51] In these cases the concentration of electrolytes is kept low by dilution. On the other hand, colloidal copper can be obtained by the action of alcohol on anhy-

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[41] Svedberg, 125, 295, 327.

[42] Amberger: *Zeit. Kolloidchemie*, 11, 99 (1912).

[43] Svedberg, 211.

[44] Svedberg, 166, 170.

[45] Gutbier and Weingärtner: *Kolloidchemische Beihefte*, 5, 211, 244 (1913).

[46] Svedberg, 204.

[47] Schottländer: *Jour. Chem. Soc.*, **68** ii, 318 (1895).

[48] Svedberg, 249; Cf. Oden: *Zeit. Kolloidchemie*, **8**, 186 (1911).

[49] Cf. Doyle: *Jour. Phys. Chem.*, **17**, 390 (1913).

[50] Svedberg, 38.

[51] Svedberg, 60–71, 101, 112.

drous copper sulphate and concentrated sulphuric acid,[52] a reaction which cannot be classified without further study. Colloidal gold can also be obtained by reduction by means of *Aspergillus oryzæ*.[53] The effect of concentration has been studied by Liversidge.[54] Colloidal metals may also be obtained by reduction in flames.[55]

2. *Reduction with Electrolysis.*—When very dilute solutions of gold, silver, and mercury salts are electrolyzed, some of the metal comes out in colloidal form.[56] Billitzer[57] obtained colloidal solutions in a similar way with salts of the less noble metals, but it is probable that the dispersed phase consisted of oxide and not of metal.[58] Lecoq[59] has prepared colloidal arsenic electrolytically, and Sansonoff[60] colloidal UO_2, the latter being stabilized by uranyl chloride.

3. *Oxidation.*—Colloidal sulphur can be obtained from the reaction[61] between H_2S and SO_2, which involves no high concentration of electrolyte. In presence of gelatine as stabilizer colloidal sulphur[62] can be obtained by oxidation of H_2S. Wöhler and Witzmann[63] have prepared iridium dioxide as a violet or blue solution. Bredig and Marek[64] have obtained colloidal manganese dioxide by the action of hydrogen peroxide on permanganate. When aurous chloride breaks down into auric chloride and gold, the latter can be obtained colloidal under suitable conditions.[65]

4. *Hydrolysis.*—Water will hydrolyze any salt until the product of concentrations of the hydroxyl and hydrogen ions reaches a value of about 10^{-14}. If the base is very sparingly soluble, the hydrolysis will run farther. Equilibrium will be reached more

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[52] Rasenfosse: *Jour. Soc. Chem. Ind.*, **30**, 133 (1911).

[53] Svedberg, 199.

[54] *Jour. Chem. Soc.*, **60**, 401 (1891).

[55] Donau: *Zeit. Kolloidchemie*, **16**, 81 (1915).

[56] Svedberg, 206.

[57] *Ber. deutsch. chem. Ges.*, **35**, 1929 (1902).

[58] Haber: *Zeit. Elektrochemie*, **8**, 551 (1902).

[59] *Comptes rendus*, **150**, 700 (1910).

[60] *Zeit. Kolloidchemie*, **8**, 96 (1911).

[61] Svedberg, 243.

[62] Himmelbaur: *Zeit. Kolloidchemie*, **4**, 307 (1909).

[63] *Zeit. anorg. Chem.*, **57**, 328 (1908).

[64] *Van Bemmelen Gedenkboek*, 342 (1910).

[65] Vanino and Roessler: *Zeit. Kolloidchemie*, **6**, 289 (1910).

rapidly if the solution is heated. If a dilute solution of ferric chloride is boiled for a few minutes and then cooled, it will not be blackened by hydrogen sulphide[66] and it will not form Prussian blue with potassium ferrocyanide.[67] On the other hand, addition of sodium sulphate or of sulphuric acid will cause a precipitation of hydrous ferric oxide. Colloidal solutions of the hydrous oxide can be obtained by hydrolysis of the acetates, the nitrates, or the chlorides, but not in general by the hydrolysis of sulphates, because sulphuric acid precipitates the colloidal solutions more readily than hydrochloric, nitric, or acetic acid. The so-called chrom-sulphuric acids are apparently special cases of colloidal solutions due to hydrolysis in sulphate solutions.[68] Colloidal solutions can also be obtained by hydrolysis of a few compounds which are not electrolytes,[69] such as silicon sulphide, ferric ethylate, and copper succinimide.

5. *Metathetical Reactions.*—When hydrogen sulphide acts on arsenious oxide, arsenious sulphide is formed practically in the absence of electrolytes. $As_2O_3 + 3H_2S = As_2S_3 + 3H_2O$. This colloidal solution can be made of the very high concentration of 3 g. As_2S_3 per 5 g. water.[70] The reaction between mercuric cyanide and hydrogen sulphide gives prussic acid in solution; but this is a very weak acid and has but slight precipitating power.[71] Colloidal sulphides can also be obtained with salts of strong acids by working in sufficiently dilute solutions.[72] In some cases sodium chloride has relatively little precipitating power, and it is therefore possible to prepare colloidal solutions of silicic acid from sodium silicate, of the so-called stannic and metastannic acids from stannic chloride and sodium stannate respectively;[73] and of tungstic acid from sodium tungstate. The tungstic acid solution can be concentrated until it contains 80 per cent. tungstic acid and has a density of over 3.2, so that glass will float in it.[74]

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[66] Wright: *Jour. Chem. Soc.*, **43**, 156 (1883).

[67] Svedberg, 260.

[68] Denham: *Zeit. anorg. Chem.*, **57**, 378 (1908); Strong: *Comptes rendus*, **150**, 1172 (1910).

[69] Svedberg, 276.

[70] Svedberg, 297.

[71] Svedberg, 302.

[72] Winssinger: *Jour. Chem. Soc.*, **54**, 911 (1888).

[73] Svedberg, 303.

[74] Müller: *Van Bemmelen Gedenkboek*, 416 (1910).

If M/20 $AgNO_3$ is mixed with M/20 KCl, KBr, or KI, so that there is a slight excess of one or the other solution,[75] more or less of the silver halide stays in suspension, being charged positively in the one case, owing to adsorption of silver ion, and charged negatively in the other case, owing to adsorption of halide ion. A salt which is readily soluble in water can be obtained in a colloidal state by working in a solvent in which the salt is practically insoluble and therefore precipitates in an extremely finely divided state.[76] Thus colloidal sodium chloride can be obtained by the interaction of sodium malonic ester and chloracetic ester in ligroin.[77]

6. *Decomposition by Light.*—Colloidal solutions can be obtained when substances are precipitated by the action of light. Svedberg[78] has studied the action of light on gold solutions, and Wigand[79] the behavior of sulphur solutions. There are also several other interesting papers along similar lines.[80]

Dispersion Methods.

1. *Removal of Agglomerating Agent.*—If a precipitate has settled from a colloidal solution owing to the addition of too much of an agglomerating agent, the precipitate may go back into apparent solution if the excess of agglomerating agent is washed out. No colloidal solution will be obtained if it is impossible to wash out the coagulating agent or if the agglomeration has gone too far.[81] If a silver halide precipitate is washed on a filter at once, the silver salt is apt to run through the filter when the excess of potassium salt has been removed and there is present only the amount which would have kept the silver halide in suspension originally. When the rare earth nitrates are precipitated by ammonia and then washed, they are liable to stay suspended in

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[75] Lottermoser: *Jour. prakt. Chem.* (2), **68**, 341 (1903); **72**, 39 (1905); **73**, 374 (1906). Cf. Drucker: *Zeit. Kolloidchemie*, **4**, 216 (1910).

[76] Böttger: *Jour. Chem. Soc.*, **36**, 107 (1878); Von Weimarn: *Zeit. Kolloidchemie*, **7**, 92 (1910); **8**, 216 (1911); **11**, 651 (1912). Cf. Pieroni: *Gazz. chim. ital.*, **43** i, 197: Paternò and Megigisciann: 439 (1913).

[77] Svedberg, 349.

[78] *Zeit. Kolloidchemie*, **6**, 238 (1910).

[79] *Zeit. phys. Chem.*, **77**, 423 (1911).

[80] Amann: *Zeit. Kolloidchemie*, **8**, 197 (1911); Galeotti: *Ibid.*, **10**, 149 (1912): Hartwagner: *Ibid.*, **16**, 79 (1915).

[81] Cf. Abegg and Schroeder: *Zeit. Kolloidchemie*, **2**, 85 (1907).

the liquid when the ammonium nitrate is nearly all removed. In alloy work stannic oxide should be washed with dilute nitric acid and not with water. Zinc sulphide is apt to form a colloidal solution when the ammonium salt is washed out,[82] and copper ferrocyanide does the same thing if all the copper sulphate is removed by washing.[83] In fact, Chautard[84] claims that the quickest way to wash a gelatinous precipitate is to evaporate the solution to dryness and heat before trying to wash. Merely evaporating on a water-bath is not always sufficient.[85]

2. *Addition of Peptizing Agent.*—Instead of washing out a precipitating agent, we may add a peptizing agent. Ammonia is very effective in suspending clay,[86] silicic acid is peptized readily by caustic soda,[87] and sulphides are peptized by hydrogen sulphide.[88] In some cases the concentration of the peptizing agent has to be high, and people usually assume the formation of compounds. Hydrous chromic oxide is peptized by caustic potash, and the apparently clear green solution does not contain any appreciable amount of dissolved chromite.[89] Hydrous copper oxide,[90] cobalt oxide,[91] and beryllium oxide form colloidal solutions in alkali. When excess of alkali is added to freshly precipitated hydrous zinc oxide, a great deal of it is peptized; but this precipitates in a short time, leaving a small amount in true solution as zincate.[92] When ammonia is added in excess to a copper salt solution, part of the copper oxide becomes colloidal and part goes into true solution, but we do not yet know the relative amounts.[93]

Chromic oxide makes the oxides of iron, cobalt, nickel, and manganese apparently soluble in caustic alkali.[94] Chromic oxide forms a colloidal solution in ammonia if enough copper salt is present.[95] Stannic acid enables iron oxide to go into colloidal solution in ammonia.[96] Molybdic acid is not precipitated by uranyl salts alone, but is in presence of tungstic acid, which carries it down and which it holds up when present in excess.[97]

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[82] Donnini: *Jour. Chem. Soc.*, **66** ii, 318 (1894).

[83] Berkeley and Hartley: *Phil. Trans.*, **206 A**, 486 (1906).

[84] *Jour. Chem. Soc.*, **26**, 527 (1873).

[85] Wright: *Ibid.*, **43**, 156 (1883); Kratz: *Ibid.*, **16**, 121 (1912).

[86] Skey: *Chem. News*, **17**, 164 (1868); **22**, 236 (1870); **34**, 142 (1876). See also Doelter: *Handbuch der Mineralchemie*, **2**, 122 (1912).

[87] Graham: *Jour. Chem. Soc.*, **17**, 324 (1864).

[88] Young: *Jour. Phys. Chem.*, **21**, 1, 14 (1917).

[89] Fischer and Herz: *Zeit. anorg. Chem.*, **31**, 352 (1902); Nagel: *Jour. Phys. Chem.*, **19**, 331 (1915).

[90] Fischer: *Zeit. anorg. Chem.*, **40**, 40 (1904).

[91] Hantzsch: *Ibid.*, **31**, 352 (1902).

[92] Bancroft: *Jour. Phys. Chem.*, **20**, 98 (1916).

[93] Grimaux: *Comptes rendus*, **98**, 1434 (1889).

[94] Northcote and Church: *Jour. Chem. Soc.*, **6**, 54 (1854); Nagel: *Jour. Phys. Chem.*, **19**, 331 (1915).

The oxides of alumina, iron, cobalt, thorium, and yttrium, when freshly precipitated, are readily peptized by hydrochloric acid[98] or by their own chlorides.[99] In fact, most oxides can be peptized to some extent by their chlorides or nitrates.[100] Ferric oxide has been peptized by aluminum chloride,[101] and freshly precipitated alumina is peptized readily by 8 per cent. acetic acid.[102] It seems probable that any substance, which will carry another into true solution when in sufficient concentration, will be adsorbed by the second, but there is no direct experimental evidence of this. Prussian blue is peptized by oxalic acid or by potassium oxalate.

At high temperatures fused baths peptize metals, forming the so-called metallic fogs[103] which are the cause of the enormous decrease in the current efficiency when the sodium or the aluminum bath is heated too hot.

The action of soap on rouge or carbon black[104] looks like a disintegration; but it is not. If a suspension of carbon black in water be filtered several times through filter-paper, the water will finally run through clear, and the carbon black will be held back by the filter-paper. If a soap solution be poured on the filter, a black filtrate is obtained and the filter-paper is no longer black. All the carbon black has passed through the filter-paper. The same thing can be done with rouge, except that a red filtrate is obtained instead of a black one. At first sight it seems as though the soap must have broken up the carbon or the rouge into finer particles, which then passed through the filter; but I think that this is erroneous. The filter-paper is porous enough at first to let through the particles of carbon or rouge, as is shown by the fact that some of the suspended matter does pass through the filter at first. The cellulose adsorbs the carbon black or the rouge, and this clogs the filter to such an extent that the pores are not large enough to let the remaining particles through. The soap removes the rouge or the carbon black from the paper because it adsorbs these substances more strongly, and everything, therefore, goes through the paper. That this is the true explanation can be shown in two ways. In the first place, the experiment does not succeed if the rouge or the carbon is too coarse. In the second place, Spring showed that we are dealing with an adsorption of carbon black by filter-paper. If the black filter-paper be reversed and washed with water, the water removes only the black, which is not in immediate contact with the paper.

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[95] Prud'homme: *Jour. Chem. Soc.*, **25**, 672 (1872).

[96] Lepez and Storch: *Monatshefte*, **10**, 283 (1889).

[97] Hitchcock: *Zeit. anorg. Chem.*, **8**, 235 (1898); Wöhler: *Zeit. Elektrochemie*, **16**, 693 (1910).

[98] Müller: *Zeit. anorg. Chem.*, **57**, 311 (1908).

[99] Graham: *Jour. Chem. Soc.*, **17**, 325 (1864).

[100] Fischer: *Zeit. anorg. Chem.*, **40**, 43 (1904); Müller: *Ber. deutsch. chem. Ges.*, **39**, 2857 (1906); *Zeit. anorg. Chem. Soc.*, **52**, 316 (1907); Szilard: *Jour. Chim. phys.*, **5**, 488, 636 (1907).

[101] Schneider: *Ber. deutsch. chem. Ges.*, **23**, 1349 (1890); *Liebig's Ann.*, **257**, 359 (1890).

[102] Bentley and Rose: *Jour. Am. Chem. Soc.*, **35**, 1490 (1913); Rose: *Zeit. Kolloidchemie*, **15**, 1 (1914).

[103] Lorenz: *Van Bemmelen Gedenkboek*, **395** (1910); *Zeit. anorg. Chem.*, **91**, 46, 57, 61 (1915).

[104] Spring: *Zeit. Kolloidchemie*, **4**, 161 (1909); **6**, 11, 109, 164 (1909); Bancroft: *Jour. Phys. Chem.*, **20**, 107 (1916).

3. *Mechanical Disintegration.*—If a solid be ground up sufficiently fine, it will necessarily form a colloidal solution for a time. This has been done experimentally by Wegelin[105] in the case of a number of metals. The addition of gelatine makes it easier to disintegrate ductile metals. Since a finely divided solid is more soluble, it is possible that it may go into solution and then precipitate in another form. This seems to happen with quartz. When reduced to an impalpable powder by long grinding, quartz can be converted into colloidal hydrous silicic acid merely by boiling with water.[106]

4. *Electrical Disintegration.*—When a direct current arc is formed under water between two wires, the metal is disintegrated and colloidal solutions of platinum, iridium, palladium, gold, silver, and cadmium may be obtained in this way.[107] Satisfactory conditions are obtained with 30 to 40 volts and 5 to 10

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[105] *Zeit. Kolloidchemie*, **14**, 65 (1914).

[106] Desch: "The Chemistry and Testing of Cement," 58 (1911).

[107] Bredig: *Zeit. Elektrochemie*, **4**, 514 (1898); *Zeit. phys. Chem.*, 31, 258 (1899).

amperes. A trace of alkali in the water causes formation of finer particles, presumably owing to the stabilizing effect of the hydroxyl ion. The disintegration is chiefly at the cathode.

The method is not satisfactory with organic liquids, because too much decomposition of the liquids takes place. Svedberg found empirically that this decomposition could be decreased very much if the current density were made as small as possible.[108] He therefore used an oscillatory discharge from an induction coil with a condenser in parallel or in series. The best results are obtained with large capacity, small self-induction, low resistance, and short arc. By this improved method Svedberg succeeded in preparing colloidal solutions of all the metals, including the alkali metals. Liquid methane, ether, and isobutyl alcohol at low temperature were especially satisfactory with the metals of the alkalies and the alkaline earths. The order of disintegration of some of the metals under similar conditions was found to be Fe, Cu, Ag, Al, Ca, Pt, Au, Zn, Sn, Cd, Sb, Tl, Bi, Pb, the iron being the least rapidly disintegrated and the lead the most rapidly disintegrated. There is no apparent relation either with the order of the boiling-points or with the order of disintegration by cathode rays or canal rays.

5. *Electrochemical Disintegration.*—With a lead cathode in caustic soda solution, the lead disintegrates when the current density exceeds a critical value, and the solution is colored black like ink with fine particles of metallic lead.[109] This is due to the temporary formation of a sodium-lead alloy, which then disintegrates in contact with water. Similar results can be obtained with cathodes of tin, bismuth, thallium, arsenic, antimony, and mercury. E. Müller[110] obtained colloidal solutions of tellurium with a tellurium cathode. This seems to be due to the formation of polytellurides, which break down and set free tellurium. In the presence of oxygen there may also be an oxidation of a telluride. Fischer[111] has obtained metallic copper in the solution by using a high current density with a copper anode in sul-

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[108] Svedberg, 424.

[109] Reed: JOUR. FRANKLIN INST., 139, 283 (1895); Bredig and Haber: *Ber. deutsch. chem. Ges.*, 31, 2741 (1898); Haber and Sack: *Zeit. Elektrochemie*, 8, 245 (1902); *Zeit. anorg. Chem.*, 34, 286 (1903).

[110] *Zeit. Elektrochemie*, 11, 521, 701 (1905); Haber: *Ibid.*, 11, 660, 827 (1905).

[111] *Ibid.*, 9, 507 (1903).

phuric acid. Cuprous sulphate is formed, which breaks down to metallic copper and cupric sulphate. This experiment has not yet been made to give colloidal copper; but this could probably be done if one were to add a suitable protecting colloid. The disintegration of all electrodes by an alternating current when the current density is high is undoubtedly due to the temporary formation and subsequent breaking down of a hydrogen or metallic alloy.[112]

Summary.

In this paper there has been given a discussion of: types of precipitates; theory of peptization; condensation methods; dispersion methods. Under condensation methods there are two subdivisions, in which the stability is due chiefly to the presence of strongly adsorbed substances or chiefly to the low concentration of agglomerating agents. Under dispersion methods the subdivisions are disintegration by removing an agglomerating agent, by adding a peptizing agent, by mechanical methods, by electrical methods, by electrochemical methods.

CORNELL UNIVERSITY.

The Corrosion of Metals by Acids. O. P. WATTS and N. D. WHIPPLE. (*Proceedings of the American Electrochemical Society*, October 3-6, 1917.)—The great economic interests involved in the corrosion of metals make it one of the most important problems which to-day engage the attention of electrochemists. The importance of galvanic couples in the corrosion and protection of metals received early recognition, but it is only in recent years that the whole problem of corrosion has been recognized as being electrochemical in its nature. It was formerly supposed that zinc dissolved in sulphuric acid because the affinity of this metal exceeded that of hydrogen for the SO_4 radical; and that for the action to go on until either the zinc or the acid was exhausted, it was only necessary that the product, zinc sulphate, should be soluble.

Among the many natural phenomena to whose explanation the theory of electrolytic dissociation has been applied is the corrosion of iron. According to this, the formation of a soluble compound is not a prerequisite to the dissolving of a metal by an acid, the metal going directly into solution as ions, and any compounds which may be formed being the result of combinations which occur after solution has taken place. From either the chemical or the ionic point of view, an electrolyte is like a room so crowded that no newcomers can enter unless some of those already present pass out to make place for them. On account of the enormous scale on which it occurs, the rusting of iron has received more attention than any other case of the corrosion of metals, and it is admitted by all that oxygen is necessary for the continuation of this process.

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[112] Haber: *Trans. Am. Electrochem. Soc.*, **2**, 192 (1902); Van Name: *Zeit. Elektrochemie*, **10**, 303 (1904).

In the extraction of gold and silver by the cyanide process, the presence of oxygen is found to be necessary in order that solution of the metals may take place with sufficient rapidity to make the process practical, the effect of the oxygen being to remove from the surface of the ore the hydrogen which is displaced by the metal when it dissolves. If the hydrogen is allowed to accumulate, its presence greatly retards solution. When amalgamated zinc is put into dilute sulphuric acid, zinc begins to dissolve, and displaces hydrogen just as if the metal were unamalgamated; but before the deposited hydrogen has become sufficient in amount to be visible or to escape as gas, the polarization produced by it, and therefore the electrical pressure necessary to deposit more hydrogen, has risen to equal the potential of zinc, when this metal is no longer capable of displacing hydrogen, and its solution ceases. Experiment indicates that the protection of zinc by amalgamation is due to the elevation of the discharge potential of hydrogen brought about by the presence of mercury, and that corrosion is promoted by the addition of an oxidizing agent to the acid. The value of nitric acid as a general solvent for metals is also shown to be due to its being at the same time an acid and an oxidizing agent.

That the inherent nature of the reaction between acids and metals is always the same is shown by experiment. On immersion in an acid, metal begins to go into solution and hydrogen is displaced. But the law of mass action applies here. As hydrogen accumulates, the driving force required to deposit more of this gas increases, and if the potential, solution pressure, or whatever other term may be chosen to designate the relative displacing power of metals in electrolytes, be very low like that of copper or silver, equilibrium is quickly reached and the action comes to a standstill. If the potential of the metal is high, as for zinc and iron, the reaction goes on, the density of the hydrogen film increases to such a point that gas begins to escape, and, as equilibrium has not yet been reached, the reaction continues as is usual in chemical changes when one of the products escapes from the field of action. The effect of an oxidizing agent is to remove one product, hydrogen, and so prevent attainment of the equilibrium which is otherwise quickly reached with the metals of low potential, copper, mercury, silver, etc.

THE SENSITOMETRY OF PHOTOGRAPHIC INTENSIFICATION.*

BY

A. H. NIETZ AND K. HUSE.

It is well known that when a negative is intensified the intensified deposit is often of a different color from that of the original negative and that this color affects the printing quality of the intensified negative; in fact, some processes of intensification depend entirely upon a change of the silver to some material having a more non-actinic color. For instance, if a negative is bleached to a silver salt and then treated with sulphide solution the silver will be converted into silver sulphide and visually will be more transparent than it was before the treatment, but the color of the silver sulphide deposit will be a brown, having much more opacity for blue light than the silver, and consequently when printed the negative will give a more contrasty print.

While intensification has been dealt with in photographic literature from the chemical standpoint and also from the practical advantages and disadvantages of various methods, very little quantitative work has been done on the effect of the color of the deposit, the only reference we have been able to find being to the work of L. P. Clerc, who measured the printing quality obtained in negatives intensified with Desalme's copper tin intensifier.[1]

In this paper we give an account of a series of measurements made on the effective printing contrast of negatives intensified by various processes, the intensified negatives ranging from those practically neutral in color to very highly colored deposits.

The legitimate function of an intensifier is that of increasing the contrast of a negative, thus acting as a corrective of under-development. Intensification may be necessary from several causes: owing to an error a negative may have been simply under-developed, in which case intensification will correct the error, or, again, if a negative is known to be badly over-exposed, then by the use of a strongly restrained developer and short development an image can be obtained in which the gradation will be approximately correct but the contrast will be insufficient, and intensification will then give the proper contrast. Some intensifiers may be used on under-exposed negatives to intensify up weak shadow detail which would otherwise be lost in printing, and thus make it possible to get a print, though in this case the gradation will be incorrect, and no process of intensification can save a serious under-exposure.

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* Communicated by Dr. C. E. K. Mees. Communication No. 58 from the Research Laboratory of the Eastman Kodak Company.

[1] A Bibliography of work on the subject of intensification published during the last seventeen years is appended to this paper.

In this paper we do not deal at all with such questions as the permanency of an intensified image or the suitability of the process for practical work; the ease of operation, uniformity of the action, capacity for repetition or for reduction, if too heavy intensification is obtained being completely ignored. In many cases the distortion of the scale of the negative by intensification is of little consequence, but if true reproduction of the tones of the subject is desired in the finished print, then the intensifier must be chosen with care, and the results shown in Fig. 5 or Table IV form a useful guide as to the selective action of various intensifiers.

EXPERIMENTAL WORK.

The experimental details of the present work require only brief description. Twenty well-known formulæ were investigated. These are shown in the following table:

A standard Seed 23 emulsion coated on patent plate glass was used. Exposures over a range of 1 : 1000 were made on a non-intermittent sensitometer, and all the plates were developed at 20° C. in a thermostat, in a paraminophenol developer. The development was for such a time that the contrast of the plates, measured by reading visually the densities on a Koenig-Martens photometer, was 0.5. The characteristic curve of the original negatives was determined from a number of plates, and the separate individuals did not differ appreciably from the mean. In all cases the plates were soaked prior to intensification, which was then carried out in duplicate in the various solutions at 20° C. The visual densities were again read and the curves of the intensified negatives plotted. In the case of highly colored images, as, for instance, the uranium deposit, the visual densities were determined by the mean of the readings through complementary red and green filters, in order to obviate the difficulty of making an intensity match with photometer fields of different color.

Ten of the methods were then chosen as being more or less

TABLE I.

No.	Bleaching solution	Blackening solution	Reference
I.	Mercuric chloride	Ammonia	Bleach according to Bennett, blackener according to B. J. Almanac
II.	Mercuric chloride	Sodium sulphite	Bleach according to Bennett, blackener according to B. J. Almanac
III.	Mercuric chloride	Paraminophenol developer	Bleach according to Bennett
IV.	Mercuric chloride	Schlippe's salt	Bleach according to Bennett, blackener according to B. J. Almanac
V.	Mercuric chloride	Ferrous oxalate	Blackener according to B. J. Almanac
VI.	Potassium, bichromate-hydrochloric acid	Amidol developer	C. Welborne Piper, B. J. Almanac
VII.	Mercuric bromide	Amidol developer	Mercuric bromide solution (Monckhoven solution A) from B. J. Almanac
VIII.	Mercuric bromide	Silver cyanide	Monckhoven. B. J. Almanac
IX.	Mercuric bromide	Sodium sulphite	Both from Bennett
X.	Mercuric iodide	Paraminophenol developer	Mercuric iodide according to Bennett
XI.	Acid silver formula in B. J. Almanac		
XII.	Uranium formula, B. J. Almanac		
XIII.	Lead ferricyanide	Sodium sulphide	B. J. Almanac
XV.	Mercuric iodide	Ammonia	Bennett
XVI.	Mercuric iodide	Schlippe's salt	Debenham, B. J., 1917, p. 186
XVII.	Potassium ferricyanide + potassium bromide	Sodium sulphide	Ordinary sepia redeveloper
XVIII.	Cupric chloride	Sodium stannite	Desalme, B. J., 1912, p. 215
XIX.	Potassium permanganate + hydrochloric acid	Caustic hydrochinon	Baker, B. J., 1906, p. 264
XX.	Potassium permanganate + hydrochloric acid	Sodium stannite	

NOTE.—The references above to the "B. J." and the "B. J. Almanac" are to the *British Journal of Photography* and the annual almanac of the same.

typical, and the photographic effect of these intensifiers was studied by the method now described in detail. For this purpose prints were made on a standard material, both from the original and the intensified negatives. The light-source was a 10-watt tungsten lamp at 110 volts; the illumination falling on the plate was measured by means of a Macbeth illuminometer, and the length of the exposure noted. The times of exposure were such as to just print through some pair of densities on the intensified and original negatives which had received identical exposures in the sensitometer. This fulfils the condition met in practice where prints are made to be comparable by just printing through the same part of the negative (as, for instance, the highest light in the subject) in the case of both the original and intensified negatives. The printing material used was Eastman Motion Picture positive film. Its characteristic curve was determined by exposing it in a non-intermittent sensitometer to the same light-source mentioned above and measuring the illumination as before. This curve represents the mean of five strips. The development of all the prints and sensitometric strips was carried out in the same solution, for the same length of time, at the standard temperature of 20° C., in the thermostat. All these were then read on the photometer as usual, giving us all the data necessary for the study of the photographic effect of intensifiers, namely: (1) the visual densities of the original negative; (2) the visual readings of the intensified negatives; (3) the same for the reproduction (*i.e.*, the prints on the positive film) from the original; (4) those for the reproduction from the intensified negatives; and (5) the characteristic curve of the printing material (positive film). We have, further, the measurements of the actual exposure in candle-meter-seconds, step for step, in the last three cases.

THE VISUAL EFFECT.

A non-selective photographic deposit is seldom met with, although certain developers give negatives which approach it. If we assume the original negative to be neutral and the deposit given by the intensifier not to alter the color, then any increase in visual density will be a direct measure of the photographic effect. Since in most cases neither of these conditions is fulfilled, the visual data are of little practical importance. However, since authors have previously used this method of presenting the facts, especially of depicting the changes in the characteristic curve of the plate, we also include such curves. Fig. 1 shows the effect on the visual plate curve when using, on Seed 23, the various intensifying solutions indicated.

We have also plotted the percentage increase in visual density against the original density of the plate. As before, this represents the actual photographic effect only in the case of neutral deposits. This is approximately the case with the mercury intensifiers, with the exception of those blackened in Schlippe's salt. The data calculated by such methods for a few representative intensifiers are shown graphically in Fig. 2.

FIG. 1.

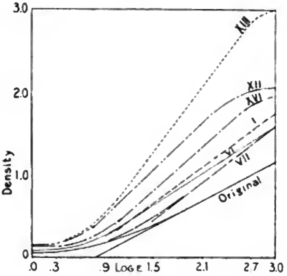
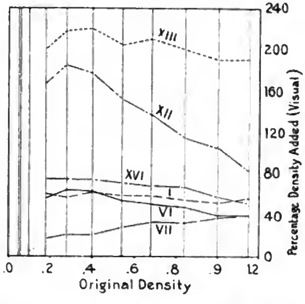


FIG. 2.

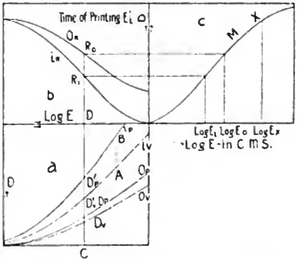


The horizontal scale in the above figure represents actual visual densities of the original plate before intensification. The vertical scale shows the percentage increase in these densities by the different intensifiers. The vertical lines on the density scale indicate the log E scale: *i.e.*, the densities corresponding to exposures increasing geometrically by the factor 2.

THE PHOTOGRAPHIC EFFECT.

In presenting a method for the study of this effect, it is necessary that the reader fully comprehend the conceptions introduced in the preceding paper by Jones and Wilsey. Since we are dealing with a special phase of the subject of reproduction, especially that concerning the photographic effect of colored deposits given by some intensifiers, we will further illustrate and explain these terms, applying them entirely to the case of intensification.

Fig. 3.



Suppose we have a sensitometric strip whose visual densities plotted against log E give the curve O_v in Fig. 3 *a*. This plate is now intensified in a solution which gives a deposit having selective transmission (*i.e.*, photographically speaking, "colored"). The visual density curve of the intensified plate may be represented by i_v. But now, owing to the color of the deposit and the fact that such deposits may pass either more or less actinic light than if they were neutral, the actual or effective density of some point A on the curve i_v may be assumed to have some other value, such as B. Similarly, all other points on i_r have other values and form a new curve i_p. This curve then represents the effective printing densities of the plate when used as a negative, and also its effective contrast. For certain well-defined conditions of printing the original and intensified plates, such as we have previously mentioned as agreeing with practice, the densities on i_p may be referred to as the photographic densities of the corresponding points on i_r. This should not be confused with the more strict use of the term by Jones and Wilsey.

Now if we examine the original plate, whose visual curve is O_r, we may find it to be practically neutral, so that its photographic density curve may coincide with its visual curve. But, on the other hand, if this is not true, then the effective density curve may be represented by O_p, and its photographic contrast will be higher or lower than that measured visually. This is usually the case for even the paraminophenol developer used, although metol and amidol[2] give very nearly neutral deposits.

The problem now before us is to devise a method of obtaining these photographic density curves. The method employed is based on the work done on the theory of reproduction by the authors of the preceding paper.

To aid in a more concrete presentation of this method, graphic means will be employed. In Fig. 3, *a*, *b*, and *c*, the curves in 3 *a* are those already described. In 3 *b* are shown the reproduction curves of the two plates, O_r and i_r, these being plotted in such a way that any point on O_R or i_R represents the deposit given by printing through the corresponding density on O_r or i_r, determined by projection downward from the points on O_R and i_R. Thus the heaviest densities on i_R correspond to the lightest on i_r; *i.e.*, by printing through the latter. Fig. 3 *c* is the characteristic curve of the printing medium (positive film), exposed to the same light-source as used in producing O_R and i_R. The density scale is the same throughout, and the exposure corresponding to any value of log E in Fig. 3 *c* is known in candle-meter-seconds. Then for any density x, produced on positive film by light of the quality transmitted by the negative, we can find the equivalent exposure E_s which produced that density by reference to the log E axis of the curve M. For example, let us find the equivalent amount of light which the density D'_v must have transmitted to produce the density R_i in the print. By projection from R_i to the curve M and thence to the log E axis, we determine directly this value, E_i, and similarly for any other point on the curve i_r.

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[2] We have found that amidol is capable of giving deposits which are photographically blue, namely, that their opacities to white light measured visually are greater than their opacities to the light, which is most active photographically.

Let

D_v = the visual density at any particular step on the original plate.
D_p = the photographic density of the same deposit.
D'_v= the visual density of the intensified plate at the same step.
D'_p= the photographic density of the latter.

The problem is to find D'_p, the photographic density of the particular step on the intensified plate, having given the visual density of the original negative, the reproductions from the original and intensified negatives, the curve of the reproducing medium developed in the same manner as the reproductions, and the illumination used in making the reproductions and in exposing the sensitometric strips of the medium. That is, we have given in the figure above, O_v, the visual curve of the original negative; O_R the curve of O_v printed on the medium; i_R, the curve of the intensified strip printed in the same manner, and M, the characteristic curve of the printing material. We must also know the exposure in candle-meter-seconds incident on the negatives in printing, as well as that given the cine-positive in the sensitometer.

Now it will be possible to find the photographic density, D'_p of the point D'_v on the curve i_r. There are two practical methods of solution. The first makes no assumptions as to the selectivity of the deposit on the original, whereas the second assumes that the original negative is neutral; *i.e.*, that $D_v = D_p$.

Method I.

In this method the photographic transmission of the deposit is obtained by measuring the ratio of the equivalent amount of light passed by the given deposit to the total amount incident upon it. As already shown, the equivalent amount of light actually passed by D'_v is determined by projection of the point R_i to the curve M, and thence to the log E axis. This gives E_i (from log E_i), the equivalent amount of light transmitted in candle-meter-seconds. The exposure used in printing the negative, E'_i is measured by means of an illuminometer in the ordinary way. The photographic transmission, T_i, equals $\frac{E_i}{E'_i}$. From this relation the density is obtained, since $D = \log \frac{I}{T}$, by definition.

We have now found the photographic density D'_p, and in the same manner the other points of the curve i_p may be determined, which is the effective photographic density curve of the intensified negative. Laborious as this method may seem, the figures on an actual case, given below, will show that it is quite practicable.

TABLE II.

$E'_i = 4360$ c.m.s.

Step on negative	D'_v	R_i	E_i	$D'_p = \log \frac{E'_i}{E_i}$
1	0.23	2.03	300	1.16
2	0.25	2.00	285	1.19
3	0.40	1.82	200	1.34
4	0.58	1.47	104	1.62
5	0.76	1.12	58	1.88
6	0.94	0.79	32	2.13
7	1.12	0.50	19	2.36
8	1.30	0.28	10	2.64
9	1.48	0.14	6.2	2.85
10	1.66	0.06	5.1	2.93
11	1.86	0.02	5.0	2.94

The values of the visual and photographic densities for the above case may be compared by consulting the second and last columns. The higher values of the photographic densities are in part due to the ultra-violet absorption of the plate-glass support of the negative.

Method II.

Assume that D_v and D_p coincide; *i.e.*, the original deposit is neutral. Assume, also, that the original and intensified plates were printed for the same time. The problem is to find D'_p with reference to D_v.

Let $T_{D'_p}$ be the photographic transmission corresponding to the photographic density D'_p and T_{D_v} be the photographic transmission of the original density taken, D_v.

Then

$$D'_p - D_v = \log \frac{1}{T_{D'_p}} - \log \frac{1}{T_{D_v}} = \log \frac{T_{D_v}}{T_{D'_p}}$$

But TD_v and TD'_p are in the same ratio as E_o and E_i, the exposures derived from the curve M, since E_o and E_i represent the amounts of light passed by D_v and D'_p respectively. Of these, E_o, E_i, and D_v are known, and hence we may say that

$$D'_p - D_v = \log \frac{TD_v}{TD'_p} = \log \frac{E_o}{E_i} = \log\ E_o - \log\ E_i$$

This difference between the logarithms of E_o and E_i gives us directly the difference in density between D_v and D'_p. Adding this to D_v gives us D'_p, the photographic density desired.

Table III gives the values obtained from one experiment.

TABLE III.

Step on negative	D_v	$\log E_o$	$\log E_i$	$\log E_o - \log E_i$	D'_p
1	0.06	2.06	....	....	0.06
2	0.06	1.98	1.90	0.08	0.14
3	0.11	1.84	1.75	0.09	0.20
4	0.20	1.68	1.55	0.13	0.33
5	0.33	1.50	1.29	0.21	0.54
6	0.50	1.26	1.00	0.26	0.76
7	0.68	1.02	0.72	0.30	0.98
8	0.91	0.78	0.46	0.32	1.23
9	1.14	0.54	0.16	0.38	1.52
10	1.37	0.26	−.19	0.45	1.82
11	1.60	0.04	−.19	0.23	1.83

It is obvious that this method cannot be applied in cases where the original and intensified plates differed greatly in density, as it is here required that the printing times be the same and also that the two negatives be printed equally through some pair of steps, usually the highest density.

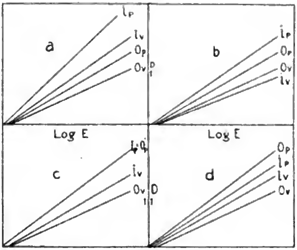
We have now all the means for determining the photographic action of different intensifiers, and it is possible to plot for any intensifier the four curves O_v, O_p, i_v, and i_p.

CLASSES OF INTENSIFICATION.

Before discussing this subject it may be well to emphasize the fact that intensification, considered from the chemical and photographic standpoints, represents two quite different conditions, and we may have the first without the latter, or the latter with very little of the first. Chemically speaking, intensification means increase in density by the addition of something to the deposit. Photographically, intensification implies that the effective contrast of the original is changed, which may occur by a change either in the color or in the arrangement of the grains, aside from increase in the bulk of the deposit. It is readily seen that we may have chemical addition to the various densities without changing the effective contrast, the added density only necessitating longer exposure. This kind of intensification is of no advantage. This point will be made clearer by the following generalizations from our experimental data. We will consider all cases of intensification, whether they result in true photographic intensification or not.

Applying the methods previously outlined, we have found that, in general, so-called intensification may be of four kinds,

FIG. 4.



as shown in the generalized curves, Fig. 4, *a*, *b*, *c*, and *d*, where the relative positions of the curves may be somewhat exaggerated to illustrate the point.

In Class *a*, Fig. 4, we have the normal case of an original negative of not too high color (but still sufficient to give a higher photographic than visual contrast), intensified by a method giving a fair degree of color in the deposit. There are both visual and photographic intensification. Such methods include Desalme's copper-tin intensifier, mercuric iodide with Schlippe's salt, mercuric iodide with an alkaline developer, and uranium.

In a special case of this class, $i_p = i_v$; *i.e.*, the intensifier gives neutral deposits. Such cases are mercuric bromide with amidol, and chromium-amidol used with an original neutral negative, in which case $i_p = i_v$ and $O_p = O_v$.

This is the most general and most useful class of intensifiers. Some others which fall in this class, if used with neutral negatives, are mercuric chloride used with various blackening agents, such as ammonia, sodium sulphite, ferrous oxalate; Monckhoven's; acid silver; and mercuric iodide with ammonia. Further relative data concerning these intensification methods will be given.

Class *b* shows visual reduction but photographic intensification. This occurs, for instance, when nothing is added to the original silver but the silver is changed to silver sulphide, as by bleaching in ferricyanide-bromide solution and blackening in sodium sulphide. Here there is a slight loss in visual density, but, as the deposit is colored and passes less actinic light than before, there is photographic intensification.

Class *c* is a special case which applies only to certain intensifiers, which give neutral deposits, used with negatives of rather high color. In this instance the photographic contrast of the original (due to the color) is far greater than its visual contrast. The intensified plate is nearly neutral in color, and, although perhaps there is visual intensification, there may be no photographic intensification. We have found this to be true with plates developed in pyro containing little sulphite (thus giving heavy color), and intensified with chromium amidol, which bleaches out some of the pyro color.

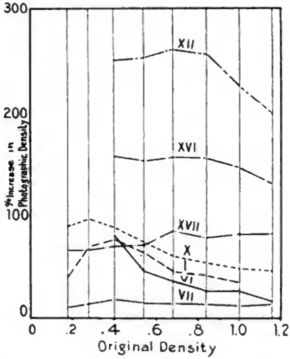
It has been possible to produce the conditions shown in Class *d*, in which we have visual intensification but photographic reduction. This was actually experimentally obtained by intensifying a pyro negative of high color in Baker's permanganate-caustic hydrochinon formula. There was slight visual intensification, but, since the pyro color was removed by the bleach, redevelopment gave a nearly neutral deposit of lower photographic contrast than the original negative. It should not be inferred that this method does not give intensification, since with neutral negatives it is quite satisfactory, giving some increase in contrast.

In the above curves, and the consideration of them, when it is indicated that, for instance, $i_p = O_p$, it does not follow that the curves are necessarily coincident, but only that they are of equal contrast and otherwise similar. This is logical, since these negatives would be exactly equivalent in printing, although one would require longer exposure than the other.

CHARACTER OF THE PHOTOGRAPHIC INTENSIFICATION.

A method of interpreting the data, analogous to that used in showing the visual effect (Fig. 2), is applied in Fig. 5, where the percentage increase in photographic density is plotted against the value of the original visual density. The ordinates represent the percentage increase and the abscissæ are the same as in Fig. 2.

FIG. 5.



A line parallel to the horizontal axis would indicate strictly proportional intensification, the same relative amount being added to each density, thereby acting to increase the contrast in the same way as longer development would. Most intensifiers approach this condition rather closely. One of the best methods in this respect, giving also vigorous intensification, consists in bleaching the negative in mercuric iodide, washing very thoroughly, and blackening in a fresh, filtered solution of Schlippe's salt (XVI).[3]

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[3] This intensifier is the one which Mr. Debenham suggested we investigate. (*B. J.*, 1917, p. 186.)

The mercuric bromide and amidol method (VII) gives proportional, although low, degree of intensification. This, however, gave the most nearly photographically neutral deposit found. Desalme's copper-tin intensifier (XVIII) deserves special mention. This was investigated by L. P. Clerc,[4] who was one of the few to consider the necessity of measuring the photographic effect and to devise means to this end. However, his method differed radically from ours, and was applied only to one or two cases, notably the copper-tin intensifier mentioned above.

We also find that this combination gives photographically proportional intensification of fair degree, and it appears that it might be a very desirable method to employ. But, as we stated originally, the general practicability (permanence, color of image, etc.) of any particular formula does not come within the scope of this paper. We wish rather to discuss intensification primarily from the standpoint of the character of the affect produced.

In connection with Desalme's intensifier, it may be of interest to note that although the deposit is visually quite highly colored, under the conditions of our experiments, it was repeatedly proved to be in effect absolutely photographically neutral. This would not be true were we using a color-sensitive printing medium. But positive film is sensitive only to ultra-violet, violet and blue, and it happens that the deposit is transparent to those wave-lengths of light to which the printing material is sensitive, whereas a yellow or yellow-brown deposit would absorb them. Hence the color of a deposit may not always be assumed to increase its photographic density.

Using a permanganate-hydrochloric acid bleach with a sodium stannite solution as a blackener (XX), on a pyro negative, we obtained a strongly colored image which showed visual intensification and still greater photographic effect.

From our experiments it is apparent that the color of the intensified deposit, as well as the degree of intensification, depends on the character of the original deposit, the latter being a function of the type of emulsion and the developer used.

COLOR COEFFICIENTS OF INTENSIFIERS.

It will be necessary to again refer to the paper by Jones and Wilsey, in which this term is defined. Practically, the color coefficient of an intensifier is that factor by which we must multiply the visual contrast value of the intensified plate to obtain its photographic contrast. For example, assume the visual contrast of the negative to be 0.8. If the color coefficient of the intensifier employed is 1.5 under the conditions of the experiment, then the effective photographic contrast of this negative will be $1.5 \times 0.8 = 1.2$.

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[4] *B. J.*, 1912, p. 215.

An application of the conception of color coefficient is made in the following, for which the reader is again referred to Fig. 3 *a*. Here the ratio of the densities D'_p and D'_v is the selectivity coefficient for the given density; that is,

$$\frac{D'_p}{D'_v} = \text{selectivity coefficient of density.}$$

The ratio of the slopes at the points D'_p and D'_v, that is,

$$\frac{\dfrac{d\,D'_p}{d \log E}}{\dfrac{d\,D'_v}{d \log E}},$$

is defined as the selectivity gradient coefficient.

In any case where the value of the selectivity gradient coefficient is constant over a range of values of log *E*, we may consider the plate as having a color coefficient. Moreover, if the plate curves have sufficient straight line to determine a definite gamma, the color coefficient is the ratio of the gammas, photographic and visual. For this special case selectivity gradient coefficient = color coefficient = $\frac{\text{photo gamma}}{\text{visual gamma}}$. These conditions are usually fulfilled by curves obtained by intensification methods. The measurement of the gammas of our curves gives us sufficient data to tabulate, for various intensifiers, the values of their color coefficients. This is simply a factor for converting the visual into the photographic contrast by taking into account the color of the deposit. We will include also a factor showing the degree of increase in contrast. This is given in the third column of the table below, and represents the ratio $\frac{\text{phot. gamma of intensified plate}}{\text{phot. gamma of original plate}}$. The rule of reproduction states that the photographic gamma of the negative multiplied by the gamma to which the reproducing medium is developed is equal to the gamma of the reproduction. In the fourth column of the following table is given the calculated value of the photographic gamma of the intensified plate;

in the fifth, the gamma to which the reproducing medium is developed; in the sixth, the observed gamma of reproduction.

It should be emphasized that the following values of the color coefficients apply only to the set of experimental conditions here met with, and that they will vary with the plate used, the character of the reproducing medium, and the quality of the light-source. But these values are useful as a means of comparing the different methods of intensification.

TABLE IV

1 Intensifier	2 Color coefficient	3 $\frac{\gamma_{ip}}{\gamma_{0p}}$	4 γ_{ip}	5 γ_M	6 Obs. γ of reprod
VII	1.00	1.15	0.78	1.10	0.85
I	1.05	1.15	0.78	1.10	1.03
VI	1.00	1.45	0.44	1.38	0.53
XVI	1.90	2.50	1.70	1.10	1.68
XIII	1.17	2.28	1.54	1.10	1.55
XII	2.52	3.50	2.40	1.10	2.52
XX	1.43	2.05	0.86	1.38	1.14
XVIII	1.00	1.93	0.54	1.38	0.74
XVII	1.60	1.33	0.48	1.38	0.54
X	1.40	1.23	0.84	1.10	1.00

For the formula reference for any of the above see Table I.

The use of the table is illustrated in part by a case of the three intensifiers VI, XVIII, and XVI (Chromium-amidol, Desalme's. and mercuric iodide with Schlippe's salt). Here we have three intensified plates, of which the first is visually neutral and the other two colored. Now the table shows (column 2) that, in the case of XVIII, the color is not effective in still further increasing the contrast, since its color coefficient is 1.00, but that with XVI the color almost doubles the effective contrast (color coefficient 1.90). The relative total degrees of intensification (increase of *contrast,* not density) are given by column 3, where we find the values to be respectively 1.45, 1.93, and 2.50. Thus XVI is the most powerful of the three.

It would be interesting to compare all intensifiers in this manner, but because of the mass of data required only representative ones were taken. Most of the mercury intensifiers are quite fairly represented by I and VII. The acid silver, Wellington, and copper intensifiers were not practicable on the emulsion used, so that unfortunately they are entirely omitted.

DISCUSSION—PRACTICAL.

It is hoped that the reader will find sufficient information in the foregoing to give him some idea as to the adaptability of the various forms of intensification. To come down to practical considerations, suppose we take four typical negatives requiring intensification, bearing in mind that the primary object of this process is the increase of photographic contrast in the negative to produce prints of the best quality possible. Four cases of negatives requiring such treatment are: (1) average landscape, over-exposed, and under-developed to save the negative; (2) average landscape, under-exposed, but having faint detail—*i.e.*, the exposure of the plate lies entirely on the toe of the H. and D. curve; (3) a line subject in black and white—typical dry-plate process work; (4) a pyro negative of high color of any of the preceding kinds.

In the first case the intensifier must be strictly corrective of under-development, thereby giving fair increase of contrast. If the negative is practically neutral, VI and X would be desirable; XVIII or XVI where more vigorous action is desired—that is, in cases of very little development.

In case two it is necessary to increase the contrast to a considerable extent. Here XVI or XII is especially applicable, the first being probably preferable.

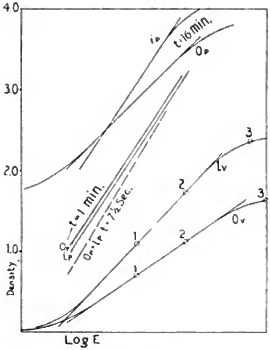
In case three it is usually desirable to have a method capable of repetition, as well as one giving excessive density with clarity of high-lights. Monckhoven's intensifier is usually recommended. Lead could be used, but is likely to give veiled high-lights.

Case four requires an intensifier of fairly high color coefficient, or, in general, one giving high intensification, particularly as the pyro color is likely to be partially or wholly removed by almost any of the processes. For this type the proper effect is given by XVI, XX, or XII.

DISCUSSION—ERRORS IN METHODS.

As previously stated, the term photographic density has been used rather loosely throughout the present paper in lieu of effective printing density. These values, also, are not in most cases the true photographic densities and are not found by the method set forth by Jones and Wilsey. But, for the problem under consideration and the definite materials used, the values obtained include the errors due to the failure of the given sensitive materials to act in accordance with known photochemical laws. A source of error of primary importance is the failure of the reciprocity law on the printing material used. This has not been thoroughly investigated, but sufficient evidence has accumulated to show that we are here concerned with it. This came about by the great difference in exposure required for the original and the intensified plates, due to the color of the latter; that is, the same densities on the reproductions of the two may have been caused by widely different exposures, $I_1\ t_1$ and $I_2\ t_2$, and these exposures may be in a different ratio from that given by reference to the curve of the printing material. Had it been possible to vary the intensity (keeping constant quality) to give the necessary exposures and to keep the time constant in the printing of both original and intensified negatives, this error would have been minimized. Further, if we could have kept the time constant and could have varied the intensity so as to give, through every deposit, an equal density on the positive film, we should have the conditions for measuring the relative true photographic densities. But practically this would not give the reproduction of the

Fig. 6.



subject, which is the aim, and the calculations would not actually apply to ordinary printing. We have, therefore, employed the empirical methods detailed above, and these give what are, no doubt, fair comparisons.

Other factors which should be taken into account are the color-sensitiveness of the printing medium and the variation of gamma with the wave-length of the light incident on this material. A full discussion of the errors involved through these causes is not the purpose of this work. Nevertheless, we investigated several cases, in so far as these conditions applied to our experimental work. An extreme case is shown by Fig. 6.

Two strips, an original highly colored pyro strip (O_v) and the same intensified by chromium-amidol to a much more nearly neutral deposit (i_v), were printed side by side to the same intensity for three different lengths of time, so as to bring the exposures on different portions of the H and D curve, as shown by the circles marked 1, 2, and 3, which indicate the highest density printed through. Had the errors due to the failure of the reciprocity law, the color sensitiveness of the material, and the gamma-wave-length relation not been involved, the three sets of experiments should have given identical values for the contrast and photographic densities. For the two lower times of printing, the photographic curves of the original and intensified plates are practically identical. On now printing sixteen times as long, the values are somewhat different, and the contrast of the pyro (original) strip has been reduced about thirty per cent. This latter effect has been repeatedly observed by Wilsey. However, this is an extreme case, and ordinarily, by printing through densities well up on the curve, and giving such exposures (with not too low intensity) that the reproduction lies almost entirely within the straight-line portion of the curve of positive film, these errors are in part avoided.

The writers wish to acknowledge their thanks to Mr. Alfred Hargreave, who assisted greatly in the experimental work.

In conclusion, an abridged bibliography is given covering some of the most important papers on intensification published within the last two decades.

ROCHESTER, N. Y.,
October, 1917.

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NOTES FROM THE U. S. BUREAU OF STANDARDS.*

A METHOD FOR TESTING CURRENT TRANSFORMERS.[1]

[ABSTRACT.]

THIS paper describes in detail a method for testing current transformers. This is a method which will be found useful in commercial plants where delicate laboratory equipment is not available and where large numbers of transformers must be tested rapidly and with moderate accuracy. Two of the most convenient of the possible modifications of the general method are described in detail.

SPECIFIC HEAT OF LIQUID AMMONIA.[2]

[ABSTRACT.]

THE Bureau's investigations of refrigeration constants have included the careful study of the thermal properties of ammonia. Such calorimetric data are of primary importance in the computations of tables adapted to the needs of the refrigeration engineer. The determination of the specific heat of liquid ammonia has been attended with considerable difficulty, but the progress in artificial refrigeration has made it a matter of great importance. The research gives the specific heat through the range −45° to +45° C. within one part in a thousand. The results are tabulated for convenience in use.

LATENT HEAT OF PRESSURE VARIATION OF LIQUID AMMONIA.[3]

[ABSTRACT.]

THIS paper describes the research of the amount of heat needed to neutralize the temperature change of a substance with a definite change of pressure. This change is sufficiently large to be taken into account in actual calorimetry. This constant was determined by three independent methods with satisfactory concordance of results.

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* Communicated by the Director.

[1] Scientific Paper No. 309.

[2] Scientific Paper No. 313.

[3] Scientific Paper No. 314.

LATENT HEAT OF VAPORIZATION OF AMMONIA.[4]

[ABSTRACT.]

This paper gives detailed description of the calorimeter designed to determine the latent heat of vaporization of ammonia. This important refrigeration constant was determined through the temperature interval −42° to +52° C. At 0° the latent heat is 301.8 calories per gramme. The results of 34 separate determinations agree with the mean within one part in one thousand.

GAS INTERFEROMETER CALIBRATION.[5]

[ABSTRACT.]

THE Rayleigh-Zeiss gas interferometer, which finds numerous applications in precision and technical gas analysis, is usually calibrated by means of gas mixtures analyzed by chemical methods. The new method here proposed requires only the use of a pressure gauge and a knowledge of the refractive indices of the gases for which the calibration is desired. It is based upon the relation between the density and the refractivity of a gas and the relation between the composition and refractivity of gas mixtures.

DURABILITY OF CEMENT DRAINTILE AND CONCRETE IN ALKALI SOILS.[6]

[ABSTRACT.]

THE report covers a coöperative investigation, under the auspices of the Bureau of Standards, into the disintegration of concrete when exposed to strongly alkalined soils and waters in the arid regions of the western part of the United States. In some cases well-fabricated structures are attacked. In other cases the structures do not appear to be affected by the salts. The purpose was to discover, if possible, the causes of such action and to ascertain the best methods of avoiding deterioration. The paper shows that the use of cement is still experimental, that porous tile are especially liable to attack, that even dense tile are subject to surface disintegration. The action seems to increase with sulphate and magnesium content. Rather full data are given and the paper is well illustrated with photographs, diagrams, and graphic charts.

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[4] Scientific Paper No. 315.

[5] Scientific Paper No. 316.

[6] Technologic Paper No. 95.

SOME UNUSUAL FEATURES IN THE MICROSTRUCTURE OF WROUGHT IRON.[7]

[ABSTRACT.]

WROUGHT iron is usually described as being of a very simple structure as revealed by the microscope, as compared with many of the alloys in commercial use. A study of the microstructure of a series of commercial wrought irons carried out at the Bureau of Standards, however, has shown the occurrence of some very peculiar and unusual variations in structure in such material. Many of the ferrite crystals, when properly prepared and etched for microscopic examination, show a decidedly banded structure instead of the homogeneous appearance usually described. This unusual structure is to be attributed to a relatively high phosphorus content in such portions and to a non-uniform distribution of this element. Although most specimens showing these unusual features of structure are of a rather poor grade, they are not characteristic of low-grade iron in general. The probable relation between such microstructural features and "fatigue" failure of such material is suggested.

GAS-MANTLE LIGHTING CONDITIONS IN TEN LARGE CITIES IN THE UNITED STATES.[8]

[ABSTRACT.]

FROM a careful inspection of about 4500 gas-mantle lamps in service in ten cities a summary of the condition of mantles, glassware, pilot light, and other particulars was made in order to determine to what extent the customer benefited through periodic maintenance service. By those observations it is found that a lamp not on regular maintenance is likely to be defective five and a half times as frequently as a lamp which is regularly maintained. Also, it is shown that, on the average, one in three of the lamps on regular maintenance was not in good condition, whereas the defects noted in the lamps not so maintained average more than one for every lamp.

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[7] Technologic Paper No. 97.

[8] Technologic Paper No. 99.

TYPICAL CASES OF THE DETERIORATION OF MUNTZ METAL (60:40 BRASS) BY SELECTIVE CORROSION.[9]

[ABSTRACT.]

THE paper reports the study of selective corrosion of Muntz metal, a material having a variety of industrial uses. The selective corrosion is illustrated by four types, including tubings, sheets, and forgings. The metal becomes red in color, very weak, and brittle by this type of corrosion. The condition favorable to such corrosion is the accelerating effect of the closely adhering deposits of chloride resulting from the attack of the metal. Other conditions accelerate the corrosion, such as contact with the more electronegative constituents, increase of temperature, and service stresses.

COMPARATIVE TESTS OF PORCELAIN LABORATORY WARE.[10]

[ABSTRACT.]

PRESENT-DAY conditions have brought upon the market several new or heretofore little known makes of chemical laboratory porcelain. In order to get an idea of their comparative value, as well as to learn just to what extent the opinion is justified that porcelain is highly resistant to the action of chemical reagents, a series of tests was made. Only five kinds could be obtained: two American, two German, and one Japanese.

When heated to 200° C. with paraffin and cooled by floating on water at room temperature, there were no failures. At 225° there was breakage of one German ("Bavarian") and both American wares.

Sudden heating in the flame of a Fletcher burner of the Méker type caused either breakage of the kinds that failed in the cooling test, or simply a cracking of the glaze when hot pieces were picked up with tongs.

When digested for two periods of six hours each with hot. 10 per cent. sodium hydroxide solution, the losses in weight were not large, although greater than with any of the other reagents used. The losses for the American wares (Herold or Coors, and Guernsey) and for the Bavarian ware amounted to about 5 mg. for 80 mm. dishes. They were nearly filled by the 50 c.c.

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[9] Technologic Paper No. 103.

[10] Technologic Paper No. 105.

of solution used. The losses for the Royal Berlin and the Japanese (" S. C. P.") were about 2 mg., except that one of the Berlin dishes lost 5.5 mg.

Digestion with 10 per cent. sodium carbonate solution for 14 hours and with concentrated sulphuric acid nearly at its boiling-point for three hours caused losses of less than 1 mg., or even apparent slight gains.

The glaze was attacked to a surprisingly small degree when the dishes were subjected to the following treatments in succession. First, 30 gm. of sodium nitrate was kept just at its melting-point for two hours, after which the dishes were washed and dried. The same amount of the salt was then slowly heated until a piece of charcoal floating on it caught fire at a temperature considerably above the melting-point. After cleaning and drying, 33 gm. of a mixture of 30 gm. of the nitrate with 3 gm. of sodium carbonate was kept just at its melting-point for two hours. The dishes were cleaned, soaked in water over night, dried, and weighed. With the excepton of a Japanese dish which then weighed 1.2 mg. less, the combined losses ranged from 0.3 to 0.6 mg.

Ferric hydroxide, spread in a thin layer over the bottom of the dish and ignited strongly, caused staining of the glaze. Digestion with hydrochloric acid (1 : 1) completely removed the ferric oxide when digested for three-quarters of an hour on the steam-bath. This test was made because it was thought that a comparatively easily soluble ferric silicate might be formed, but the slight losses, none of which was greater than 0.2 mg., showed that this is not the case.

In brief, the five kinds of porcelain are about equally resistant to the action of reagents, but only the Japanese and Royal Berlin wares successfully withstood sudden changes in temperature.

SAFETY FOR THE HOUSEHOLD.[11]

[ABSTRACT.]

THE safety of the home is the subject of a new pamphlet just issued by the Bureau of Standards, Department of Commerce, entitled " Safety for the Household, Bureau of Standards Circular No. 75." An interesting account of household hazards is given. The topics are discussed clearly in a manner which would afford a basis for popular education in "Safety First." The dangers from electricity, gas, fire, lightning, household chemicals, and the other common causes of accident are recited and many actual cases are described. The purpose is to aid in removing needless risk and fear, and to develop intelligent caution where the hazard cannot be entirely avoided.

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[11] Circular No. 75.

The hazards of the home have increased in modern times from the service of gas and electricity and the use of such dangerous articles as matches, volatile oils, poisons, and the like. The use of energy in the home necessarily involves some risk, which intelligent planning and care will reduce to a minimum.

Caution alone is not enough, since many of the dangers are not even suspected. The nature of such unknown hazards must be made plain. The circular emphasizes the seriousness of some of the risks not generally known, gives simple cautions, and aims to guide the formation of habits of carefulness. The circular also suggests effective home equipment to minimize the risks involved, and aims to encourage public measures to provide safety for the household and community.

It is intended, not to increase fear of accident, but rather to remove the causes and the need for alarm. The sense of safety to be gained by observing these cautions would alone justify the careful study of this new circular. This circular completes the series of three popular household circulars which deal with measurements, materials, and safety. These form a valuable addition by the Bureau of Standards to the literature on household management.

The appalling loss of life from avoidable causes and injury to person and property make the pamphlet especially timely. It is believed that thousands of human lives could be saved and accidents reduced to the minimum if the precautions suggested are followed. Copies of this circular can be purchased at a nominal cost of 15 cents per copy from the Superintendent of Documents, Government Printing Office, Washington, D. C.

GAS TESTING.[13]

This circular may be regarded as a supplement to Bureau of Standards Circular No. 48, "Standard Methods of Gas Testing." The correction tables are arranged in a sequence most convenient for use in connection with the proposed record sheet. The record forms for calorimeter tests which are shown in the circular have been used for some time and found to be complete and convenient. It is hoped that these forms will be adopted wherever possible, so that there will be greater uniformity in operating methods and the records used. The Bureau is willing to loan the original plates for preparation of electrotypes for these blanks to any one desiring to print them.

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[13] Circular No. 65.

Mineral Springs of Alaska. Anon. (*U. S. Geological Survey Press Bulletin*, No. 349, December, 1917.)—Hot springs are widely distributed in Alaska, many of them yielding water that is near the boiling-point and remaining unfrozen the year round. During the Russian occupation of the territory primitive bathing-houses were built at several hot springs, notably near Sitka, and the hygienic value of the springs was recognized. In recent years more elaborate bathing establishments have been constructed at several accessible hot springs, but some that are more difficult of access are occasionally visited by prospectors. The demand for more accurate information about the qualities of the thermal waters led to an investigation whose results are set forth in a recent publication of the United States Geological Survey, Department of the Interior—"Mineral Springs of Alaska," by Gerald A. Waring (Water Supply Paper 418).

To obtain material for this report Mr. Waring spent the field season of 1915 in Alaska. He examined 23 springs and obtained notes on 37 others whose existence was not before known to the Survey. Among the springs described by Mr. Waring are a number that yield carbonated water, and others whose water is strongly sulphuretted or salty. More hot springs have been found in southeastern Alaska than in the interior, perhaps because this part of the territory is best known, and relatively few have been found in northern Alaska. Nevertheless, the report describes hot springs at 21 places in the Yukon Basin and at 5 in Seward Peninsula. The report is illustrated by sketch maps that show the location of many of the springs.

The quality of the spring waters was determined by analyzing samples collected by Mr. Waring, and is discussed in connection with their manner of occurrence and source.

The report contains also a brief chapter on the chemical character of some of the surface waters, by Richard B. Dole and Alfred A. Chambers, who have brought together all the available analyses. Most of the analyses represent samples collected by exploring parties in 1914 and 1915. The discussion of the quality of the waters of the Yukon is based on samples collected daily at Anvik from August

23, 1915, to April 19, 1916, and from June 14 to August 16, 1916. Analyses of these samples will form part of a special report on the quality of the surface waters of Alaska.

Copies of Water-Supply Paper 418 may be obtained without charge by applying to the Director, United States Geological Survey, Washington, D. C.

Accommodation and Chromatism of the Eye. ANON. (*The Optical Journal and Review of Optometry*, vol. 41, No. 2, p, 94, January 3, 1918.)—The human eye, because of its power of accommodation, is a refractive system with a mobile focus. A lens has no mobility of focus at all. The eye that is completely presbyopic also has no mobility of focus, and when a lens is prescribed for the use of a person completely presbyopic, there can be no mobility of focus. Sometimes elderly persons demand glasses with which they can see equally well far and near. If they do not still have sufficient accommodation, this demand cannot be met. Those who take this stand will be more easily convinced that they are asking impossibilities when they are told that what they need is another pair of eyes; that the ability to focus far and near is not a property of the lens, but of the human eye, which is lost in later life. When this power of the eye is lost, glasses cannot restore it; all the glasses can do is to make vision clear for just one point, far or near.

Chromatic aberration is not noticeable in the eye under usual conditions, and yet the retinal image of any bright object is not a simple image. It is multiple in nature and made of several different colors. The reason we do not see the colors is because the eye is very sensitive to yellow rays and much less so to all the others, the result being that we unconsciously disregard all but the image formed by the yellow rays.

By looking at the small bright light through glass that only passes red and violet light, as for instance cobalt-blue glass, and at the same time wearing a correction that keeps the accommodation relaxed, we can measure the chromatism of the eye. Using the cobalt-blue glass in this way, and focussing for the violet, which puts the red out of focus, we compare the width of the red border to the light with the width of the light, and then make a calculation on the basis of the diameter of the pupil of the observing eye, the result of which will express in diopters the amount of chromatic aberration, which is usually found to be about 1.50.

While, as a rule, a person is not conscious of colored borders to bright objects, yet there are some exceptions where, for instance, the letters of test charts are seen bordered with colors. Usually in such cases the sight is slightly blurred, and removing the blur causes the colors to disappear. When this is not the case, there is no remedy for the condition; the subject must become accustomed to his chromatism and learn by practice to disregard it.

NOTES FROM THE RESEARCH DIVISION, ELECTRICAL ENGINEERING DEPARTMENT, MASSACHUSETTS INSTITUTE OF TECHNOLOGY.*

EDGE EFFECT IN COPPER BARS AT ELECTRIC-LIGHTING FREQUENCIES.

MEASUREMENTS have been made of the extra resistance due to non-uniform current density in large copper bars carrying alternating currents at 60 and also at 25 cycles per second. The bars were loaned for the test by the courtesy of the General Electric Company. They were in lengths of 6.1 metres (20 feet) and of cross-section 102 mm. × 6.35 mm. (4 inches × ¼ inch), such as are commonly employed in bus-bar construction behind the low-tension switchboards of central stations supplying electric light and power. Tests were made of the effective resistance offered by simple rectangular loops of these bars, connected end to end by special standard metallic but non-magnetic clamps. The distance between the going and returning sides of the loop was kept at 60 cm. (23.5 inches). The length of the loop was 17.8 metres (58.3 feet) when testing single bars in series. The total direct-current resistance of this loop, including 36 metres of bar and the clamp connections, was 955 microhms at 20° C. On account of this very low resistance, difficulty was experienced in measuring the alternating-current effective resistance with the necessary precision. Three different methods of measurement were used, and many trials had to be made before the results of all three could be found in satisfactory agreement. After about six months' testing and comparison, the following concordant results were obtained with alternating currents of from 100 to 350 ampères:

Cycles/second frequency	Bar temperature	R′/R Resistance ratio
60.8	29° C.	1.3
24	29° C.	1.1

These results indicate that the edge effect in such large copper bars is of considerable practical importance at ordinary lighting and power frequencies. It is commonly supposed that at 60~ the extra alternating-current resistance in such conductors is trivial.

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* Communicated by the Director.

In the case of these bars, however, the effective resistance to alternating currents over and above their direct-current resistance was, according to these results, 30 per cent. at 60.8∼and 10 per cent. at 24∼. This relatively large increment in effective resistance accompanying alternating-current flow is almost entirely attributable to edge effect. The skin effect in the bars is negligible at these frequencies. Thus the formula for skin effect in an indefinitely wide sheet, as originally developed by Lord Rayleigh, shows that the extra resistance of an indefinitely wide bar 6.35 mm. thick would be only 0.1 per cent.; or the resistance ratio would be only 1.001 at 60∼and 29° C. In such a 6.35-mm. sheet the alternating-current density would be nearly uniform at all depths below the surface. The alternating-current density in the surface skin for 60∼would not be much greater than that at the midplane 3.175 mm. deep. In a bar 102 mm. wide, however, the alternating-current density near the edges is much greater, at 60∼ than at or near the middle of the width. The alternating current distributes itself in such a manner as to crowd toward the edges of the bar and to denude the central areas. The phenomenon of edge effect is merely a particular aspect of skin effect. In each case the current avoids the central areas and crowds into the remote outlying regions of the cross-section. Circular copper rods of the same cross-section as these bars (645 sq. mm. or 1 sq. inch) would have, at 60∼and 25° C., a resistance ratio R'/R of 1.13, or only 13 per cent. extra resistance due to skin effect, less than half the extra resistance found in the bars at this frequency. Of course, such equisectional rods, on the other hand, would have much smaller cooling surface than the bars, per metre of length, and would therefore heat up much more with powerful alternating currents. In cases where it was considered important to reduce the extra resistance of edge effect, it would be possible to do so by using a tubular section for the conductors, augmenting the diameter and reducing the thickness of the tube wall until the desired limit had been obtained. Such tubes are naturally devoid of edge effect, and only skin effect has to be considered with them. From mechanical and structural standpoints, such large tube busbars might be very awkward to employ.

Some further measurements were made with various shorter rectangular loops made up of these copper bars in parallel groupings. The largest resistance ratio found was 2.2, at 61∼and

27° C., in the case of a loop 4.9 metres long (19.3 feet), with its sides 5.1 cm. (2 inches) apart. Each side of this loop was composed of three of these copper bars in parallel, clamped together at the ends, over spacing pieces to keep the individual bars 6.35 metres (0.25 inch) apart. The aggregate conductor was thus 102 mm. wide × 31.8 mm. thick (4 inches × 1.25 inches). The alternating testing current was over 1000 ampères in this case. With the same 3-bar loop broadened out to a separating distance of 63.5 cm. (25 inches) between the sides, the resistance ratio R'/R fell off to 2.0 at 61 ~ and 25° C.

Pipe Corrosion in Domestic Service. T. F. PAYNE. (A. M. Byers Company, Bulletin No. 30, Pittsburgh, September, 1917.)—The rapid rusting of water pipes in the Pittsburgh district, especially those carrying hot water, has frequently been commented on, and in the beginning of 1917 the subject was taken up for discussion and investigation by the Pittsburgh Board of Trade. In that respect Pittsburgh is not different from most other large cities in the United States, where similar complaints are common. So far, however, no systematic investigation had been made by a house-to-house canvass of buildings to ascertain the difference in life between different kinds of pipe. The A. M. Byers Company, therefore, arranged for such an investigation with the object of determining all the pertinent facts which might aid property owners in meeting the rust question in the most efficient manner.

After several unsuccessful attempts to obtain accurate data from private residences and other buildings, it appeared, for many reasons, that apartment buildings offered the best field for investigation, and observations in 125 apartment buildings were recorded. While the conditions of service vary to a great extent according to the size of pipe used, its thickness, the quantity of water used, its temperature, etc., there is a difference of corrosive effect even between different parts of the piping in the same building, it being conclusively shown that: (1) The corrosion of hot-water lines gradually decreases with the distance from the boiler. (2) The corrosion is more severe in mains or horizontal lines than in vertical lines conveying either hot or cold water.

Altogether, the records show a remarkable similarity of performance of each of the different kinds of pipe used in the various buildings. Under the most severe service conditions, in a total of 125 buildings, genuine wrought-iron pipe proved to have double the life of soft steel or "wrought pipe," and brass proved to be only slightly better than wrought iron, and certainly not enough better to warrant the many times greater first cost. The average life of hot-water mains of wrought iron is 14 years, and of steel 7 years.

Constructional Steels and Their Heat Treatment. F. C. A. H. LANTSBERRY. (*Journal of the Society of Chemical Industry*, vol. xxxvi, No. 18, p. 983, September 29, 1917.)—Steels are essentially alloys of carbon with iron; silicon and manganese are added in the process of manufacture for well-known reasons. Alloy steels are simply steels to which other elements or an excess of silicon and manganese have been added. Until about twenty years ago alloys were practically never used except for some highly specialized work. Modern requirements, however, demanded properties that plain steels in their condition as then known were incapable of meeting. Resort was then had to the addition of various alloying elements to the steels with the object of improving their mechanical properties. Developments in electrical appliances also demanded the improvement of magnet steels. Further, the introduction of harder steels increased machining difficulties, and improvements in cutting tools followed. At the present time the addition elements for the production of alloy steels are chromium, tungsten, nickel, silicon, manganese, vanadium, molybdenum, cobalt, and titanium.

When originally introduced, alloy steels owed their merit to superior mechanical properties in their untreated state. This superiority was often more imaginary than real. It was soon discovered that by heat-treating these steels still further improvements in their mechanical properties could be effected, and it became apparent to metallurgists that the full value was obtained only after some process of heat-treatment. It is only within the last few years that this knowledge has been extensively applied, and even at the present time much alloy steel is used in its crude state when the cheaper plain steel will serve equally well.

The simple steels used for constructional purposes contain from 0.1 to 0.75 per cent. carbon. In the annealed state their mechanical properties are substantially linear functions of the carbon content and are included between the limits of 16 and 45 tons per square inch yield stress and 20 and 65 tons per square inch ultimate stress, with a contraction in area from 70 to 30 per cent. The elongation being to a large extent a function of the shape and relative dimensions of the test piece, no useful purpose is served by quoting it. By oil-quenching and tempering the mechanical properties of a 0.5 per cent. carbon, steel can be varied between 25 and 87 tons per square inch yield stress and 40 and 102 tons per square inch ultimate stress, with a contraction varying between 50 and 0 per cent. Still higher values, with less contraction, are attainable with higher carbon content. It is obvious, therefore, that the mechanical properties of ordinary carbon steels can be vastly improved by heat-treatment, and in yield and ultimate strength compare favorably with alloy steels. The alloy steels, however, have the advantage of maintaining a high contraction value with high yield and ultimate stresses, and, generally speaking, the higher the contraction the greater will be the resistance to shock.

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Gardner, H. A., Senior Lieut.	Naval Flying Corps	Washington
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Masters, Frank M., Major	Ordnance Dept., U.S.R.	Washington
Maxfield, H. H., Lieut. Col.	19th Railway Engineers, U.S.N.A.	
Mershon, Ralph D., Major	E.O.R.C., U.S.A.	New York
Miller, Fred. J., Major	Ordnance Reserve Corps	Centre Bridge, Penna.
Owens, Major R. B.	Signal Corps	France
Parrish, T. R., 1st Lieut.	Signal Corps	Washington
Reber, Samuel, Colonel	Signal Corps, U.S.A.	New York
Richardson, Chas. E., 1st Lieut.	30th Engineers, U.S.R. (Gas and Flame)	France
Spackman, Henry S., Major	Engineer Officers' Reserve Corps	France
Spruance, W. C., Jr., Lt. Col.	Ordnance Dept., National Army	Chevy Chase, Md.
Squier, Geo. O., Major General	Chief Signal Officer, U.S.A.	
Stanford, H. R., Civil Engineer	U. S. Navy	Boston
Thomas, Geo. C., Jr., Captain	Aero Service Squadron 96, Aviation Section, Signal Corps	France
Tilghman, B. C., Captain	A.D.C., 28th Div. Headquarters, U.S.A.	
Vogleson, J. A., Major	Sanitary Corps (Surgeon General's Dept.)	Fort Oglethorpe
Wagner, Fred. H., Major	Ordnance Reserve Corps, Nitrate Division	Washington
Wagner, Fred. H., Jr. Sergeant	Co. E., 304th Engineers	Camp Meade
Wetherill, W. C., Ensign	U. S. Navy	
Wood, Edw. R., Jr., Captain	18th Field Artillery, U.S.N.A.	El Paso, Texas

Name and rank	Branch of service	Location
Worrell, Howard Sellers	3rd Officers' Training Camp	Fortress Monroe
Wyckoff, A. B., Lieut.	U. S. Navy	Ontario, Cal.
Yale, A. W. Major	Medical Reserve Corps, Gas Division	Camp Kearney
Yorke, George M., Major	Signal Corps, U.S.R.	New York

MEMBERS DOING CIVILIAN WORK FOR THE UNITED STATES GOVERNMENT

Name	Appointment	Location
Anderson, Robt. J.	Engineer of Tests of Ordnance, War Dept., U.S.A.	Brier Hill Steel Co.
Balls, William H.	Ships Draughtsman	Phila. Navy Yard
Bancroft, Joseph	Secretary, Local Board No. 1	Wilmington
Baskerville, Charles	Working with Bureau of Mines, Ordnance Dept., (Gas Warfare, Shells, etc.)	New York
Bodine, Samuel T.	Vice-Chairman, District Exemption Board, No. 1, Eastern Judicial District of Penna.	Philadelphia
Burnham, George, Jr.	Dept. of Civilian Service and Relief, Public Safety Committee of Pennsylvania	Philadelphia
Charles, Bernard S.	Ordnance Inspector, U. S. Navy	Allentown, Pa.
Comey, Arthur M.	Chairman, Sub-Committee on Explosives, Chemistry Committee, National Research Council	Chester, Pa.
Condict, G. Herbert	Naval Consulting Board, Member Committee of Examiners	Plainfield, N. J.
Cope, Thomas D.	National Research Council	Washington
Day Charles	Member of Army War Council	Washington
Delano, Frederic A.	Member of Federal Reserve Board	Washington
Douredoure, B. L.	Student at Franklin Institute Radio School	Philadelphia
Dunn, Gano	Chairman, Engineering Committee, National Research Council	New York
Garrison, Frank Lynwood	Chairman, U. S. Manganese Commission	Philadelphia
Gilpin, Francis H.	Mechanical Engineer, Research Section, Picatinny Arsenal	Dover, N. J.
Halberstadt, Baird	Federal Fuel Administrator for Schuylkill Co., Penna.	Pottsville
Hyde, Edward P.	National Research Council, Sub-Committee on Monocular vs. Binocular Field-Glasses (Chairman).	Cleveland
Insull, Samuel	Chairman, Illinois State Council of Defense	Chicago
Kennelly, A. E.	Conducting special course in radio-engineering for the U. S. Signal Corps, in conjunction with Prof. E. C. Chaffee	Harvard Univ.
Lloyd, E. W.	Asst. Secretary, Illinois State Council of Defense	Chicago
Lucke, C. E.	Civilian Director, U. S. Navy Gas Engine School	Columbia Univ.
Merrick, J. Hartley	Director, Bureau of Camp Service, Penna. Div., American Red Cross	Philadelphia

Name	Appointment	Location
Milne, David	Treasurer, American Red Cross General Hospital No. 1	Philadelphia
Morris, Effingham B.	Treasurer, Committee of Public Safety, State of Pennsylvania	Philadelphia
Nichols, Carroll, B.	Fuel Administration	Washington
Nichols, Wm. H.	Committee on Chemicals, Advisory Council of National Defense, Consulting Chemist, Bureau of Mines	New York
Penrose, R. A. F., Jr.	Member of Geology Committee of the National Research Council	Philadelphia
Rautenstrauch, Walter	Committee of the National Research Council	New York
Richards, Joseph W.	Member of Naval Consulting Board	So. Bethlehem, Penn.
Robins, Thomas	Member and Secretary of the Naval Consulting Board	New York
Sperry, Elmer A.	Member of Naval Consulting Board	Brooklyn, N.Y.
Sprague, Frank J.	Member of Naval Consulting Board, Chairman, Committee on Electricity and Shipbuilding	
Stradling, George F.	Recruiting for Aviation Section, S.O.R.C.	Philadelphia
Talbot, Henry P.	Member of Advisory Board, Bureau of Mines, (Gas Defense)	Cambridge, Mass.
Thomson, Elihu	National Research Council in cooperation with Council of National Defense	Swampscott, Mass.

Please send additional information and corrections to the Secretary.

(Proceedings of the Stated Meeting held Wednesday, February 20, 1918.)

HALL OF THE FRANKLIN INSTITUTE,
PHILADELPHIA, February 20, 1918.

PRESIDENT DR. WALTON CLARK *in the Chair.*

Additions to membership since last report, 10.

Reports of progress were presented by the Committee on Science and the Arts and the Committee on Library. The standing committees for the year 1918–'19 were announced.

The paper of the evening, entitled "Dyestuffs," was presented by Louis Joseph Mátos, Ph.D., Technical Chemist and Chemical Engineer, The Cassella Color Company, New York City. The speaker gave a brief account of the development of dyeing and color-making. A description was also given of the sources, production, and applications of dyestuffs, both natural and of coal-tar origin, as well as the development of the various related industries in this country since the beginning of the war. Reference was made to the present opportunities for closer relations between the engineer and chemist in the field of inorganic chemistry and to the training of chemists for such work. The subject was illustrated by lantern slides.

After a brief discussion, the thanks of the meeting were extended to the speaker.

Adjourned.

GEORGE A. HOADLEY,
Acting Secretary.

STANDING COMMITTEES, 1918.

OF THE BOARD.

ELECTION AND RESIGNATION.

Alfred W. Gibbs, Chairman,
Kern Dodge,
W. C. L. Eglin,
George R. Henderson,
George D. Rosengarten.

ENDOWMENT.

Coleman Sellers, Jr., Chairman,
Alfred C. Harrison,
Charles A. Hexamer,
G. H. Clamer,
William C. Wetherill.

EXECUTIVE.

E. H. Sanborn, Chairman,
Charles Day,
Walton Forstall,
A. W. Gibbs,
Alfred C. Harrison.

EXHIBITIONS.

Francis T. Chambers, Chairman,
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Benjamin Franklin,
Nathan Hayward,
Marshall S. Morgan.

INSTRUCTION.

Lawrence T. Paul, Chairman,
George A. Hoadley,
Harry F. Keller,
Edward V. McCaffrey,
James S. Rogers.

PUBLICATIONS.

Louis E. Levy, Chairman,
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SECTIONAL ARRANGEMENTS.

Harry F. Keller, Chairman,
Gellert Alleman,
Charles Day,
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STOCKS AND FINANCE.

Walton Forstall, Chairman,
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OF THE INSTITUTE.

LIBRARY.

H. J. M. Creighton,
George A. Hoadley,
Harry F. Keller,
Gaetano Lanza,
Henry Leffmann,
Louis E. Levy,
Marshall S. Morgan,
Paul Spencer,
George F. Stradling,
William C. Wetherill.

MEETINGS.

Gellert Alleman,
Charles Baskerville,
G. H. Clamer,
A. S. Cushman,
George R. Henderson,
Herbert E. Ives,
A. E. Kennelly,
M. M. Price,
James S. Rogers,
George D. Rosengarten.

MUSEUM.

J. Snowden Bell,
Hugo Bilgram,
Arthur L. Church,
Fred H. Colvin,
Henry F. Colvin,
Charles Day,
George A. Hoadley,
Henry Howson,
Alex. E. Outerbridge, Jr.,
Coleman Sellers, Jr.

COMMITTEE ON SCIENCE AND THE ARTS.

(Abstract of Proceedings of the Stated Meeting held Wednesday, February 6, 1918.)

HALL OF THE FRANKLIN INSTITUTE,
PHILADELPHIA, February 6, 1918.

MR. BENJAMIN FRANKLIN, *Chairman pro tem.*

The following reports were presented for first reading:

No. 2656.—Automatic Operation of Water Gas Sets.
No. 2690.—Havard Coal Meter.

The following report was presented for final action:

No. 2704.—Sweetland Filter Press.
Recommended that the John Scott Legacy Medal and Premium be awarded to Ernest J. Sweetland, of Upper Montclair, N. J.

GEORGE A. HOADLEY,
Acting Secretary.

SECTIONS.

Section of Physics and Chemistry.—A joint meeting of the Section and the Philadelphia Section of the Illuminating Engineering Society and the Physics Club of Philadelphia was held in the Hall of the Institute on Thursday evening, January 10, 1918, at 8 o'clock. Dr. George A. Hoadley introduced Mr. Walton Forstall as presiding officer of the evening. The minutes of the previous meeting were read and approved.

Herbert E. Ives, Ph.D., Physicist of the United Gas Improvement Company, Philadelphia, delivered an address on "The Physics of the Welsbach Mantle." The relationship between the chemical composition, the temperature, and the luminous efficiency of a mantle were discussed, with special reference to mantles composed of oxides of the rare earths, or of mixtures of these oxides. A report was made concerning the relative proportion of radiated, convected, and conducted heat produced by the consumption of energy in a gas light. The address was illustrated with experiments and lantern slides.

The paper was discussed by Prof. Monroe B. Snyder, Messrs. Forstall, Henderson, and Gulbrandson, and Doctors Hoadley and Ives. On motion of Dr. Walton Clark, a vote of thanks was extended to Doctor Ives. After adjournment, the audience was permitted to inspect an exhibit of raw materials, finished mantles, and mantle accessories shown by the Welsbach Company.

JOSEPH S. HEPBURN,
Secretary.

Section of Physics and Chemistry.—A meeting of the Section was held in the Hall of the Institute on Thursday evening, January 24, 1918, at 8 o'clock, with Dr. Harry F. Keller in the chair. The minutes of the previous meeting were approved as read.

Lucius Polk Brown, Director of the Bureau of Food and Drugs, Department of Health, New York City, N. Y., delivered a lecture on "Food Wastes—Some Causes and Remedies." The course of foodstuffs was traced from the producer to the consumer; the wastes, which occur in the producer's hands, during transit, during distribution in the city, in the household and restaurant, and in trade channels, were described, and methods for their elimination were suggested.

The paper was discussed by Professor Lawall, Dr. Carl. Hering, Mr. C. S. Brinton, and others. On motion of Dr. George A. Hoadley, a vote of thanks was extended to Mr. Brown. The meeting then adjourned.

Section of Physics and Chemistry.—A meeting of the Section was held in the Hall of the Institute on Thursday evening, January 31, 1918, at 8 o'clock, with Dr. Henry H. Donaldson in the chair. The minutes of the previous meeting were read and approved.

Ross G. Harrison, M.D., Ph. D., of Yale University, New Haven, Conn., delivered a lecture on "Animal Transplantation." The history of animal transplantation was traced, and the applications of grafting in modern surgery were reviewed, with special reference to the replacement of lost parts and the assistance of wound healing. A detailed account was then given of the use of grafting in embryological researches on problems of development. The lecture concluded with a description of the growth *in vitro* of isolated living tissue. The lecture was illustrated with lantern slides.

The paper was discussed by Doctors Eldridge, Donaldson, and Harrison. A vote of thanks was extended to Doctor Harrison, and the meeting adjourned.

JOSEPH S. HEPBURN,
Secretary.

Electrical Section.—A joint meeting of the Section and the Philadelphia Section of the American Institute of Electrical Engineers was held in the Hall of the Institute on Thursday evening, February 7, 1918, at 8 o'clock. The meeting was presided over by Mr. N. Hayward, chairman of the A. I. E. E. The lecture was delivered by Edwin F. Northrup, Ph.D., of the Palmer Physical Laboratory, Princeton University, and his subject was "The Application of Oscillatory Currents to Heating and Electric Furnace Practice."

Doctor Northrup's remarks were limited to the induction type of furnace, and he gave a demonstration at the blackboard of the theory and the formulæ involved in their design. He then described the theory of oscillatory currents as obtained from condensers. Such currents, used in connection with transformers, may cause large quantities of heat to be generated, which can be used both experimentally and commercially in the reduction of metals. It was shown that the best results are obtained by using frequencies of 10,000 to 25,000 cycles per second.

He then proceeded to describe a new form of furnace which had been designed by him. The condenser consisted of glass and brass plates, the former being used because cheaper than mica. The crucible consisted of nicrome or graphite, depending upon the nature of the contents, and the furnace possessed several novel features and contained no iron in its construction. As only one furnace had been completed, and it but recently, no exhaustive tests had been made, but with an 18-kilowatt furnace an efficiency of 55 per cent. had been attained, and experiments indicated that this should be increased to 70 per cent. or more. The principal loss occurs in the air-gap, while the loss in the condenser is small if properly constructed.

After considerable discussion the meeting adjourned.

H. CALVERT,
Secretary.

MEMBERSHIP NOTES.

ELECTIONS TO MEMBERSHIP.

(*Stated Meeting, Board of Managers, February 13, 1918.*)

LIFE.

MR. THOMAS BILYEU, Mechanical Engineer, Hillsboro, Ore.

RESIDENT.

MR. GEORGE A. BUCKLEY, Real Estate, Ardmore, Pa.
MR. WILLIAM STEELL JACKSON, Patent Attorney, 1001 Chestnut Street, Philadelphia, Pa.
DR. WALTER L. PYLE, Physician, 1931 Chestnut Street, Philadelphia, Pa.

NON-RESIDENT.

DR. M. C. BURT, Chemist, Atlas Powder Company, and for mail, 231 West Broad Street, Tamaqua, Pa.
MR. JESSE COATES, National Research Council, 1023 Sixteenth Street, N. W., Washington, D. C.
DR. WALTER O. SNELLING, Research Chemist, 208 North Fifth Street, Allentown, Pa.

ASSOCIATE.

MR. HERMAN EILBERG, Chemist, 2411 South Fourth Street, Philadelphia, Pa.
MR. ANTHONY DE H. HOADLEY, Student, 518 Walnut Lane, Swarthmore, Pa.
MR. CHARLES H. MASLAND, 2D, Chemical Engineer, 1202 Stratford Avenue, Melrose Park, Pa.
MR. JOSEPH VALASEK, Physicist, 2069 Park Road, Washington, D. C.

CHANGES OF ADDRESS.

PROF. WILLIAM H. BALLS, 1422 Snyder Avenue, Philadelphia, Pa.
MR. C. E. BENNETT, The Kenilworth Apartments, Ponce de Leon Avenue, Atlanta, Ga.

MR. LEON C. BIBBER, P. O. Box 331, Newport News, Va.
MR. R. BURDETTE DALE, 31 West Tenth Street, Erie, Pa.
LIEUT. S. B. ECKERT, Commander 9th Aero Squadron, American Expeditionary Force, via New York.
DR. H. FOERSTERLING, care of The Abor Farm, Jamesburg, N. J.
LIEUT. E. F. KINGSBURY, 1023 Sixteenth Street, N. W., Washington, D. C.
MR. WM. J. MCGURTY, 3904 Brookline Avenue, Arlington, Md.
COL. SAMUEL REBER, Signal Office, Eastern Department, Maritime Building, 8–10 Bridge Street, New York City, N. Y.
LIEUT. COL. W. C. SPRUANCE, JR., 6400 Rockville Road, Chevy Chase, Md.
MR. L. H. THULLEN, 211 South Jefferson Avenue, Grand Rapids, Mich.
MR. CHARLES S. VADNER, Box 539, Reno, Nev.
MAJOR JOHN A. VOGLESON, Sanitary Corps, N. A., Camp Greenleaf, Fort Oglethorpe, Ga.
MR. L. D. VORCE, care of Canadian Salt Company, Ltd., Windsor, Ontario.
MAJOR GEORGE M. YORKE, 195 Broadway, New York City, N. Y.

NECROLOGY.

George Edward Bartol, a life member of The Franklin Institute, a founder and for twenty-six years president of the Philadelphia Bourse, died November 13, ultimo, at the University Hospital, in this city, after an illness of several weeks. He was born in Philadelphia, January 29, 1858, the son of Barnabas H. Bartol, a resident of Philadelphia after his removal from Freeport, Maine, in 1847. To Mr. Barnabas H. Bartol the Institute is indebted for the foundation of the Bartol Scholarship in the Department of Mechanical Drawing of the Institute's night schools.

At the age of 16 young Bartol, after going through the courses of a private school, was given the experience of a nine months' cruise before the mast in a sailing vessel connected with his father's sugar refining business, the Grocers' Sugar Company, and on his return was placed as engineer's apprentice in the refinery. In a short time he became assistant superintendent of the refinery, and in 1881, in his twenty-third year, came into its complete control. Six years later, in 1887, he withdrew from this occupation to engage in the foreign commission business, making his connections in Great Britain, Belgium, and Germany, and during his stay abroad took time to supplement his early education by attending courses of lectures at Heidelberg and in Brussels.

His experiences in the prosecution of his merchandising and commission business brought Mr. Bartol to a realization of the advantages of unified effort in the development of commercial possibilities, as indicated by the activities of the bourse organizations in the chief European cities, and, strongly imbued with public spirit as he was, he was impelled to take the lead in the establishment of a similar institution in Philadelphia. Through his efforts in this direction the Philadelphia Bourse was founded under his presidency in 1891, and from then on that organization claimed such constantly increasing measure of his time and attention that, although at one time he had become the largest exporter of grain in Philadelphia, he gave up his business in 1897 and devoted himself entirely to the activities of the Bourse and to the advancement of the mercantile and maritime interests of his native city.

Mr. Bartol was a leader in movements for the development of the port of Philadelphia and in furthering unity of action and coöperative effort among the trades interests of the city. Within the last two years he organized and directed the "Via Philadelphia Movement," in which all the leading business bodies of the city are affiliated, and was a leading spirit in the reorganization and improvement of the Philadelphia Belt Line Railroad. He was also active in the organization of the Joint Committee on Reasonable Regulation of Railroads, which initiated a national campaign for a more equitable and unified system of railroad regulation. The widely reputed "Philadelphia Plan" for regulation through regional connections was prepared chiefly by him.

Mr. Bartol was a recognized authority on waterway as well as railroad transportation, and was the first president of the National Rivers and Harbors Congress. He was a member of the Inland Water Transportation Committee of the Council of National Defence, and shortly before his death he completed for the Government a survey of the possibilities of the canals and other inland waterways of the eastern United States for immediate use in relieving the railroads of part of their great burden of war transportation. Mr. Bartol was a director of the Girard National Bank, the Western New York and Pennsylvania Railroad, the Dexter Portland Cement Company, the C. Howard Hunt Pen Company, and the Philadelphia Belt Line Railroad Company, and was a member of the Union League, the Corinthian Yacht Club, and of the Second Presbyterian Church. He is survived by his wife, Jane Newman Grier Bartol, two daughters, and two sons, the latter, George E. Bartol, Jr., and J. Grier Bartol, having taken up army service at the Officers' Training Camp at Fort Oglethorpe, and having since been awarded commissions in the Aviation Corps and the Artillery.

LIBRARY NOTES.

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Welsbach Company, Bulletins Nos. 1 to 16, Relating to the Incandescent Gas Lighting Industry. Gloucester, N. J., 1907–11. (From the Company.)

BOOK NOTICES.

TREATISE ON APPLIED ANALYTICAL CHEMISTRY: METHODS AND STANDARDS FOR THE CHEMICAL ANALYSIS OF THE PRINCIPAL INDUSTRIAL AND FOOD PRODUCTS, by Prof. Vittorio Villavecchia, with collaborators. Translated by Thomas H. Pope, B.S., A.C.G.I., F.I.C., University of Birmingham. Philadelphia, P. Blakiston's Son & Company, 1918, vol. 1, 470 pages, contents and index, illustrations, 8vo. Price, $6.

The name and work of Professor Villavecchia have long been known to those engaged in commercial analysis. As director of the laboratories of the Italian Customs service, he has had an extended experience with testing the raw materials and manufactured articles of commerce. The work is to appear in two volumes. The present volume covers the subjects: Waters, Chemical Products (general commercial inorganic and organic substances), Fertilizers, Cement Materials, Metals and Alloys, Fuels, Coal-tar and Products, Mineral Oils and Derivatives, Fats and Waxes, Industrial Treatment of Fatty Substances.

All these topics are treated carefully and clearly, and there is a great deal of information given in a compact form. The article on Metals and Alloys covers about one hundred and thirty pages and gives a large amount of interesting information concerning the many special alloys that have of late years been introduced to meet the necessities of high-speed tools, motor cars, and flying machines.

The work is well translated, well printed on excellent paper; indeed, in view of the cost and scarcity of good paper it is a question whether a cheaper grade might not have answered. It would not have made so handsome a book, but would have been as serviceable to the laboratory.

The American reviewer will be especially interested in the extent to which the author and translator have utilized American work, that has been so fertile of late years in all the fields covered by the book. He will be much disappointed that only one reference to an American periodical is discoverable, and that to an article twenty-two years old, with both the name of the author and the page reference inexact.

HENRY LEFFMANN.

PUBLICATIONS RECEIVED.

Agricultural Bacteriology: A Study of the Relation of Germ Life to the Farm, with Laboratory Experiments for Students, By. H. W. Conn, Ph.D. Third edition, revised by Harold Joel Conn. 357 pages, illustrations, 12mo. Philadelphia, P. Blakiston's Son & Co., 1918. Price, $2.

U. S. Coast and Geodetic Survey: Terrestrial Magnetism: United States Magnetic Tables and Magnetic Charts for 1915, by Daniel L. Hazard, chief, Division of Terrestrial Magnetism. 256 pages, maps, 8vo. Washington, Government Printing Office, 1917.

North Carolina Geological and Economic Survey: Biennial Report of the State Geologist, 1915–16. 202 pages, illustrations, quarto. Bulletin No. 27, altitudes in North Carolina, compiled by the North Carolina Geological and Economic Survey. 124 pages, quarto. Raleigh, State Printers, 1917.

U. S. Bureau of Mines: Bulletin 148, Petroleum Technology 37, Methods for Increasing the Recovery from Oil Sands, by J. O. Lewis. 128 pages, illustrations, 8vo. Bulletin 153, The Mining Industry in the Territory of Alaska during the Calendar Year 1916, by Sumner S. Smith, U. S. Mine Inspector. 89 pages, plate, 8vo. Technical Paper 174, Suggestions for the Safe Operation of Gasoline Engines in Mines, by R. H. Kudlich and Edwin Higgins. 19 pages, illustrations, 8vo. Technical Paper 133, Directions for Sampling Coal for Shipment or Delivery, by George S. Pope. 15 pages, plate, 8vo. Monthly Statement of Coal-mine Fatalities in the United States, October, 1917, compiled by Albert H. Fay. 31 pages, 8vo. Washington, Government Printing Office, 1917.

U. S. Bureau of Foreign and Domestic Commerce: Annual Report of the chief for the Fiscal Year Ended June 30, 1917. 77 pages, 8vo. Washington, Government Printing Office, 1917.

Cultivation of Medicinal Plants in the United States. R. P. FISCHELIS. (*The Catalyst*, vol. 2, No. 10, p. 3, December, 1917.)—In the strictly pharmaceutical field. the shortage of crude drugs has been felt more or less keenly since 1914, and much misinformation and little information of value have been circulated on the subject. Stocks of many crude drugs have been exhausted and the cultivation of medicinal plants has not yet assumed any great proportions in the United States. Those drugs which were obtained from

Europe were not cultivated, but grew wild there. It was therefore a simple matter to have them gathered and prepared for market at comparatively slight cost. The cultivation of medicinal plants in the United States requires expert labor, the production of artificial conditions of soil and moisture in order to provide as nearly as possible the conditions under which the plants grow in their native habitat, and considerable investment of money.

Drug plants have been raised on an experimental scale by the Government and in the drug gardens of various colleges, but it is a very different undertaking to raise them on a commercial scale. American growers of crude drugs were confronted with the necessity of increasing the value of the plants in order to overcome the high cost of cultivation. It was soon found that cross-pollination would not produce plants containing more active constituent than they do normally, but by careful selection of seed it has been possible to increase the amount of active constituent in such plants as belladonna, digitalis, etc., to three or four times what the Pharmacopœia requires. Furthermore, advanced methods of harvesting these plants have made it possible to secure three or four harvestings in one season, whereas in former years one or two was the limit.

Low Visibility Paints. ANON. (*Graphite*, vol. 20, No. 2, p. 4283, February, 1918.)—Low visibility and service are important points when choosing a paint. Ornamentation is not always the first consideration. It may be more important to soften the lines and blend the color into the horizon. For instance, it may be important not to emphasize a house in the woods, but to make its lines blend with the trees that surround it. Certainly in the case of smokestacks, gas holders, etc., it is important to blend them with the horizon as much as possible, as it is not always desirable in a town or city that they should be conspicuous. At one time the American naval vessels were all painted white. The British Navy during the bombardment of Alexandria had its vessels painted black, with yellow smokestacks. This gave a splendid mark to the enemy gunners.

About the year 1902 these ideas began to change. Service and low visibility became matters of importance. The British Navy authorities then ordered that the warships be painted a horizon gray, and civilians thought the change offended the art sense, etc. It did, but art is not the main point in the dress of a warship. At the great battle off the coast of Jutland it was reported that many of the German warships succeeded in getting away from the combined British fleets because of "low visibility." The German ships were painted a "dirty gray" so that they might blend with misty weather and with the horizon. Commercial ships are now also painted in this manner so as to escape submarines, and we have seen some ships on which wavy lines of gray, green, or other colors are used.

CURRENT TOPICS

Oil Shales Reserved for the Navy. Anon. (*U. S. Geological Survey Press Bulletin,* No. 349, December, 1917.)—In the annual report of the Director of the Geological Survey, Department of the Interior, just made public, attention is called to the creation of two naval oil reserves in Colorado and Utah. The Survey has been investigating the oil shales of the United States that give the most promise of yielding a commercial supply of oil, and has explored large areas in Colorado and Utah that contain immence deposits of such shales, some of which carry 30 to 50 gallons of oil to the ton. This potential resource is estimated by the Survey in terms of billions of barrels of oil, which it is believed can be economically extracted from the shales, possibly in competition with the petroleum at present prices. It is therefore of special interest to note that during the last year two oil-shale reserves were created for the use of the Navy, one of 45,440 acres in Colorado and one of 86,584 acres in Utah.

General classification of oil-shale land was continued by the Survey during the year, the work covering large areas. Geologic examination of the oil-shale region of the West has shown that the oil shales in Utah and Colorado contain enormous quantities of petroleum. They also contain a considerable percentage of nitrogen, aggregating a vast supply, which can be recovered as a by-product in the refining of the shale and used either as a fertilizer or in the manufacture of explosives.

History of the Manhattan Railway Company's System. F. W. Gardiner and S. Johannesson. (*Proceedings of the American Society of Civil Engineers,* vol. 43, No. 10, p. 2043, December, 1917.)—Elevated railroad construction in New York City was commenced on July 1, 1867, when "The West Side and Yonkers Railway Company" started to erect an experimental section on Greenwich Street, between Battery Place and Cortlandt Street. This section was completed on July 2, 1868, and was a single-track railroad. The line was extended as a single-track road through Greenwich Street and Ninth Avenue to Thirtieth Street during the following two years, and was opened for traffic on February 14, 1870. The structure was on the east side of the street through Greenwich Street and on the west side through Ninth Avenue. The trains were operated by an endless chain, driven by stationary engines below the surface of the street, at Cortlandt, Franklin, Bank, and Twenty-second Streets. This method of traction did not prove successful, and traffic was abandoned in November, 1870, but was resumed again on April 20, 1871, using a dummy engine, the "Pioneer," weighing five tons and drawing three cars.

In the fall of 1871 the bondholders of the company organized under the General Railroad Laws as "The New York Elevated Railroad Company." In October, 1872, the company announced that it would receive passengers at Morris, Dey, Canal, Twelfth, and Twenty-ninth Streets. During the following years the line was gradually extended northward on Ninth Avenue—in 1873 to Thirty-fourth Street, in 1875 to Forty-second Street, and in 1876 to Fifty-ninth Street. In 1877 a double-track extension was built to South Ferry, and during 1878 a double track was completed and opened for traffic over the whole line. At the same time the rolling stock was increased, consisting, in 1874, of 10 cars and 6 engines and, in 1876, of 21 cars and 15 engines. The original structure on the east side of Greenwich Street and on the west side of Ninth Avenue, between Battery Place and Fifty-ninth Street, was torn down in sections and replaced by a new structure, which was completed in May, 1880.

In October, 1877, the New York Elevated Railroad Company commenced the construction of the Third Avenue Line, and opened it for traffic on August 26, 1878, between South Ferry and Forty-second Street. The line was extended and opened for traffic to 129th Street before the end of the year. The Forty-second Street branch to Grand Central Station was also opened in August, 1878; the City Hall branch, from Chatham Square to City Hall, was completed in March, 1879, and the Thirty-fourth Street branch to the East River was opened in July, 1880.

Another company, the Metropolitan Railway Company, formerly called the Gilbert Elevated Railway Company, in the spring of 1876 commenced to construct what is now called the Sixth Avenue Line, between Morris Street and Fifty-ninth Street, but became involved in legal difficulties, and the road was not opened until June, 1878. The same company opened the line through Fifty-third Street from Sixth to Ninth Avenues and the line in Ninth and Eighth Avenues from Fifty-ninth to 155th Street in 1878. The Metropolitan Elevated Railway Company also constructed an east-side line from Chatham Square through Division Street, Allen Street, and First Avenue to Nineteenth Street, which was opened in September, 1879; the remainder of the line—which is now the Second Avenue Line—to 129th Street, was opened in 1880.

In May, 1879, the New York Elevated Railroad Company and the Metropolitan Elevated Railway Company were leased to the Manhattan Railway Company (first organized in November, 1875) for 999 years, "in order, by means of one management, to avoid dangers of level crossings and also to perfect the system of rapid transit." This was known at the time as the Tripartite Agreement of May 20, 1879. The authorized rates of fares at that time were 10 cents for any distance of less than five miles, and not to exceed 15 cents for a through passage between the Battery and the Harlem

River, except on "Commission Trains," which ran between 5.20 and 7.20 A.M. and between 5 and 7 P.M., when the corresponding rates were 5 and 7 cents. The 5-cent fare was introduced for all hours on all lines on November 1, 1886. It is interesting to note that as early as January 20, 1879, the collection of tickets by the conductors was abolished, the passengers on and after that date depositing their tickets in the ticket boxes provided at the exit gates, on leaving the trains. This was changed on June 21, 1880, to the present method of depositing the tickets in cancelling boxes at the entrance.

Another elevated railroad company, the Suburban Rapid Transit Company, was originally chartered in October, 1880, but did not commence construction until November, 1883, when the work on the foundations for the Harlem River Bridge at 129th Street and Second Avenue was started. The road was opened for traffic between 128th and 143d Streets in 1886, extended to 166th Street and Third Avenue in 1887, to 169th Street in 1888, and to 177th Street in 1891. The line from 177th Street to Fordham Road was opened in July, 1901, and from Fordham Road to Bronx Park in May, 1902.

On June 4, 1891, the Manhattan Railway Company assumed control of the Suburban Rapid Transit Company, and from that date, therefore, was in possession of all the elevated lines in Manhattan and The Bronx.

During 1899 to 1901 the whole system was equipped for electric traction, and since June 25, 1903, all trains have been run by electric motive power.

On April 1, 1903, the Manhattan Railway Company leased the system to the Interborough Rapid Transit Company, which since then has operated the lines.

Pig Iron from Scrap Steel. ANON. (*Mining and Scientific Press,* vol. 115, No. 26, p. 936, December 29, 1917.)—The electric furnace has made possible what may be regarded as almost a revolution in the steel industry. It is the conversion of scrap steel or iron back into pig iron. What may be called "synthetic pig iron" is now a commercial product; in other words, the original constituents of pig iron are being made to reunite in the condition originally assumed. This unusual achievement is another evidence of the adaptability of electrical energy to the production of results impossible by any other means. The new process is being applied commercially in a large electric-steel plant in the eastern part of the United States, high-grade or low-phosphorus pig iron being made directly from ordinary scrap steel. Not only is pig iron being produced in large quantities, but wash-metal and iron and steel castings are made in the same furnaces. The pig iron sells in the open market as a competitor with regular low-phosphorus blast-furnace iron, the wash-metal goes to crucible-steel makers, and the iron castings are sold to near-by users, or else are used by the company in its rolling mill.

The idea is not new, but this is the first record of its commercial exploitation in the United States. Late in 1912, Horace W. Lash, of the Garrett-Cromwell Engineering Company, of Cleveland, organized a corporation for the purpose of converting scrap steel and iron into pig iron in an electric furnace on the Pacific coast. Pig iron being expensive in that part of the country, and the fact that it could be made by this process without the use of coke, charcoal, or coal, which are not cheaply available there, were the impelling reasons. It is not known that the company carried out its plans, but it is understood that Robert Trumbull, an engineer at one time identified with Heroult in his efforts to introduce his electric furnace in America, is now producing pig iron from scrap in an electric furnace in Canada.

The Eastern concern that has been successfully operating, as stated above, is known as the Sweetser-Bainbridge Metal Alloy Corporation of Watervliet, N. Y. For several months it has been producing from a Ludlum electric furnace. About 50 tons per day is the present output from two 5-ton furnaces.

Water Resources of Hawaii. ANON. (*U. S. Geological Survey Press Bulletin*, No. 341, November, 1917.)—The rainfall on the Hawaiian Islands varies from a few inches to nearly 400 inches a year, and, as much of the fertile area is made to produce through irrigation, the study of the water supply of the islands is a matter of great importance. It is stated that the critical period is approaching in Hawaiian agriculture, and that the time has come in the utilization of water when it becomes necessary to have all the information possible regarding its available sources.

Among the principal crops of the islands are sugar, rice, and taro; many fine pineapples also are grown. Sugar is by far the most important product, and large areas planted in cane depend entirely on irrigation. Some of the lands are naturally adapted to the growing of rice, but require a certain quantity of water, varying in amount with the stage of the crop. Taro is also an important crop, furnishing the staple food for a considerable part of the population; it requires a continual application of water during its growth. Taro is a large plant which yields a root tasting somewhat like an Irish potato. It is grown to a considerable extent in the United States as an ornamental plant and is popularly known as elephant's ear.

In making plans for power, irrigation, municipal water supply, and other projects involving the use of water from any stream it is necessary to have data from which the total flow of the stream and its variation from day to day throughout the year can be obtained. Since November, 1909, a study of the streams of Hawaii has been carried on at gauging stations maintained by the United States Geological Survey, Department of the Interior, in coöperation with the Territory of Hawaii, and Water-Supply Paper 430, "Surface Water Supply of Hawaii," just issued by the Geological Survey, Department of the Interior, gives the results of this study during the period from July 1, 1913, to June 30, 1915. It contains a list of the gauging stations maintained on the islands, estimates of the daily and monthly discharge of the streams, and the results of studies of rainfall at many points. Water-Supply Paper 318 gives the results of water-resource investigations in Hawaii for the years 1909–1911, Water-Supply Paper 336 the work for 1912, and 373 the work for 1913.

These reports will be valuable to engineers and others engaged in developing the water resources of the islands. Water-Supply Papers 318 and 373 are no longer available for free distribution, but may be purchased from the Superintendent of Documents, Washington, D. C., for 50 cents and 40 cents, respectively. Copies of Nos. 336 and 430 may be obtained without cost on application to the Director, United States Geological Survey, Washington, D. C.

Color from the Physical Point of View. H. C. RICHARDS. (*Proceedings of the Illuminating Engineering Society*, October 11, 1917.)—The color of light may be expressed in terms of its hue, brightness, and saturation; or it may be defined by the relative amounts of three standard colors, as red, green, and blue, which must be added to produce the same impression on the eye. But these are more or less subjective definitions. From a physical point of view the character of a light (*i.e.*, its color) is determined by the distribution of energy among the different wave-lengths in the spectrum. The translation of this information into terms of color sensation is effected by the study of the effect of light of various wave-lengths in producing the fundamental color sensations.

It should be noticed, however, that the converse is not true; *i.e.*, it is not possible to infer without ambiguity the constitution of a light from observations of its color, since various combinations of spectral constituents will yield the same color sensation. There is here a contrast between the sister sciences of optics and acoustics. The characteristics which distinguish sounds—pitch, intensity, and quality—correspond completely to the three physical properties of a wavelength, amplitude and form a complexity, while in optics the coördination of the properties of hue, brightness, and saturation to the corresponding physical properties is imperfect.

Two classes of illuminants are included in the physical laws determining the color of a light source: those having discontinuous spectra and those having continuous spectra. To the former belong luminous vapors, to the latter incandescent solids and liquids. The classes differ not only in their physical structure but also in the method by which the luminosity is produced; for, while continuous spectra are produced by heat alone, the production of a discontinuous spectrum requires for the most part electrical or chemical action, though in some cases heat is used to stimulate such action.

Sources giving discontinuous or bright line spectra furnish us with the most brilliant and varied color lights. These are produced by salts volatilized by a flame or by the electric discharge through rarefied gases. Here we have all degrees of complexity, from light of but one wave-length, as in the yellow of sodium or the green of thallium, to that of mercury vapor, where there are half a dozen constituents, and so on to more complex cases, as that of iron with thousands of lines. When the wave-lengths present are predominantly in one portion of the spectrum, the light will be more or less richly colored, as for instance in the brilliant red of the strontium flame or of the neon vacuum tube. When the energy is more or less uniformly distributed through the spectrum the light becomes whitish in character, as with the Moore carbon dioxide tube or even the mercury vapor light. By far the greater number of illuminants belong to the class of those having continuous spectra, and among these we must include our most important or standard light—that of the sun. In these the prominent part is played by temperature. It is a familiar phenomenon that as the temperature of a body is raised it changes in color as the body becomes successively red hot, yellow hot, and white hot.

The light of a source is usually modified by transmitting it through a selectively absorbing medium, such as colored glass. This subtracts from the light its different constituents in varying proportion so as to modify its spectral quality. By this means one light source may be made to produce the same effect as another, as has been done in the last few years with the "daylight glass" shade, which modifies the light of a tungsten bulb to approximate the quality of daylight. Another but less usual method of modifying the color of a light is by selective reflection. Instances of this are to be found in the gilding of the reflectors of automobile headlamps to produce a yellower beam, in the effect of reflection from the walls in interior lighting, and in summer in the slightly green tinge of daylight from light reflected by foliage. Again, a light of given quality may be produced by combining sources of different kinds. This method has also been used to produce artificial daylight. It is also the basis of some processes of color photography, where any color is imitated by the addition in various proportions of red, green, and blue lights.

Simplicity of Fastening Design. ANON. (*Machinery*, vol. 24, No. 4, p. 304, December, 1917.)—Machine designers often miss a golden opportunity for saving in the cost of manufacture of details by being too careful in proportioning the fastening details. It is not uncommon to find a machine well designed in all its essential mechanism which requires a large variety of screws, studs, and bolts to hold the parts together. The screws may have been carefully selected with due consideration of their respective stresses and functions, but that scrupulous care may have resulted in carrying out the design with too little regard for the cost of production. It might have been better, from the manufacturing standpoint, to have made some of the screws larger than actually required for strength, or to have used two small screws in place of one large one, so that as many as possible could be of one size and type. Thus time would be saved in drilling and tapping, and less variety of screws would be required in stock.

An 18-inch engine lathe is being built in which the fastening screws, with a few exceptions, are ⅝-inch diameter and of the same length. In some places, of course, a ⅝-inch screw is too large, and in others it is necessary to use two screws instead of one. Some holes have to be drilled and tapped deeper than is really necessary; but the gain outweighs the loss. By standardizing to one diameter and length of screw only, much time is saved in machining and assembling, and the job of making and keeping stock is simplified.

Substantial economies have been effected in the manufacture of typewriters by standardizing machine screw body sizes and heads and by eliminating many odd shapes and lengths. Instead of using thirty different screws in a carriage, only seven are used in the same part of a new machine. The same company has also discontinued using some gauges of sheet-metal stock, and now uses as few as practicable. In these times, when it is extremely difficult to get anything but standard sheets from the mills, it is highly important that the use of odd gauges be avoided; but if their use can be avoided in abnormal times, why not always in the interests of simple stock keeping and efficient manufacture?

Bolts fitted in reamed holes rarely, if ever, require hexagon or square heads. The fit of the body in the hole should be sufficient to resist the torsion of the nut when tightening or loosening it, but the practice of using forged hexagon head bolts is general in locomotive building and repair shops. Considerable saving can be made by using round head bolts with narrow shoulders under the heads. The height of the head need not be more than three-fourths the body diameter. Bolts of this shape can be turned from bar stock when needed for quick repairs.

The Metric System and the Maintenance of Standards. F. J. MILLER. (*Proceedings of the American Metric Association,* December 28–29, 1917.)—One of the sayings which the opponents of every step in the direction of the increased use of the metric system are particularly fond of quoting is: "Measures of length are irrevocably linked to the past." This saying is attributed to one of our most prominent and honored machine-tool builders, and it is quite true in a certain sense, but not true in the sense in which it is usually employed or interpreted. It is a phrase which appeals with peculiar force to machine builders, but when it is used in arguments against the use of the metric system the literal meaning of the phrase appears to be misunderstood. The metric system can make headway, in machine construction at least, only by steps taken by those who at the time of taking such steps believe them to be advantageous from the pecuniary point of view. Such steps are now being taken in unusual numbers for that reason.

If, instead of the saying quoted, we say, "Things made to specified dimensions so as to secure interchangeability are irrevocably linked to the past," which is generally true, and then if we recognize that these things need not be in the least changed by the adoption of the metric system, the meaning is clear. It is unwise to try to convince machine builders that our established standards of screw-threads, pipe-threads, etc., can be changed; they are admittedly "irrevocably linked to the past." The Briggs standard for pipe-threads, for instance, is now in universal use in this country. It has a taper of 0.75 inch per foot, has 11½ threads per inch, and has other dimensions specified in inch terms. Comparatively few of those who use or install pipe or fittings know or need to know what these dimensions really are; but they do know that, no matter where they may go to do a job of pipe fitting, or where they may get their supplies for the job, interchangeability is assured, and that is all they need concern themselves about; but this interchangeability is of the most vital importance, and metric opponents do not in the least overstate the case when they attempt to describe the confusion, delay, and expense that would be caused by any change in this standard.

Much the same may be said of numerous other standards, and metric advocates will do well to recognize the correctness of this attitude and to face it frankly and openly. In the metric-using shops of Continental Europe the Whitworth standard screw-threads are in general use, and those standards have been retained there along with the general use of the metric system, notwithstanding that the Whitworth thread is of English origin and has its dimensions defined in terms of the inch. It was for a long time claimed by metric opponents that the meter and the yard are incommensurable, and that any magnitude expressed in metric terms could not be exactly expressed in inch terms, but if any one were to ask the United States Bureau of Standards to verify a bar with marks upon it supposed to be one yard apart, for perfectly sound reasons, the real distance between these marks would be determined by reference to the metric bar, and the work would be more accurately done than would be possible by reference to any existing yard bar. The whole force of the opposition to the introduction of the metric system rests upon the assumption that the adoption of the metric system entails the abandonment of this or any other standard which it is worth while to preserve, an assumption which is quite useful to the anti-metric propaganda, but which is entirely without foundation in fact.

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THE PROBLEM OF COAL SUPPLY.*

BY

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THE subject assigned to me for discussion this evening by your secretary, and my friend, Doctor Owens, "The Problem of Coal Supply," is somewhat misleading, for I think I shall be able to show in a very few words at the outset that the problem in our fuel troubles is not one of supply but of production, transportation, and distribution.

The total area in the United States underlain by anthracite, bituminous coal, and lignite is about 460,000 square miles. Practically all of the anthracite is found in a relatively small area in the northeastern part of Pennsylvania. The productive part of this region is less than 500 square miles in extent, less than 0.11 of 1 per cent. of the total coal field, but the anthracite production to the close of 1915 has amounted to 2,626,500,000 tons, or nearly one-fourth of that of the entire United States.

The most important of the bituminous coal fields from a present producing standpoint, and so far as the quality of the coal is concerned, is the Appalachian region, extending from the northern part of western Pennsylvania and eastern Ohio to the central part of Alabama. The highest grades of bituminous coals (or

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* Presented at a meeting of the Mining and Metallurgical Section held Thursday, November 8, 1917.

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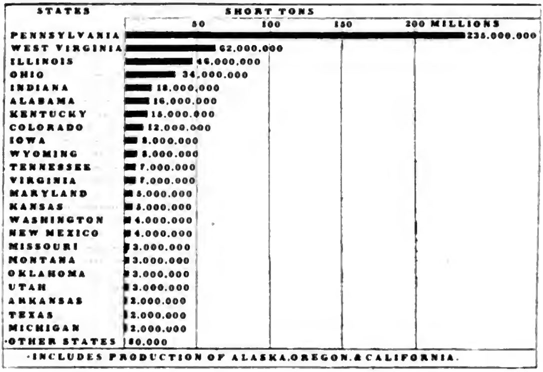
what we generally term semi-bituminous, because of their high carbon, low volatile, and consequently "smokeless" quality) occur along the eastern border of this region. The principal coking coal fields are also east of a line drawn through the centre of the region from north to south, as are likewise the better grades of steam coals and the Cumberland or Georges Creek (Maryland) smithing coals. Among the other higher grade coals well known to the coal trade that are produced on this eastern border of the Appalachian region are the Clearfield (steam), Connellsville (coking), Youghiogheny (gas), Somerset (steam), Pocahontas and



Production of coal in the United States by states.

New River (steam and coking), Jellico (domestic), Clinchfield (steam), and Warrior (steam and coking).

The coals of the interior province, extending from eastern Michigan on the north to Texas on the south, are of wider extent than those of the Appalachian region, but are decidedly inferior in quality to the coals of the Appalachian province. They possess little or no coking quality, though some of them, like the block coal mined near Terre Haute, Ind., have been used raw in iron furnaces. This quality of coal is largely already worked out. The combined contents of the Appalachian and interior provinces is something over 1,000,000,000,000 tons, of which a little more than half is in the Appalachian fields and a little less than half in the coal fields of the interior states.

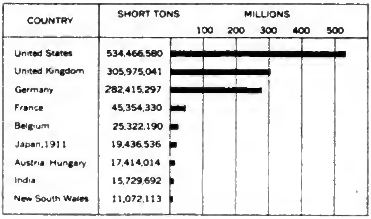
The coal fields of the Great Plains and Rocky Mountains far overshadow all the more easterly fields in extent and ultimate productivity, but in quality the most of the contents are much below even those of the interior province. There are some true bituminous coals, and two or three places where the bituminous coals have been locally changed to anthracite, but they are for the most part lignites and sub-bituminous coals, the latter being a grade between the true lignite and true bituminous coal. The Rocky Mountain and Great Plains coal fields embrace some 178,022 square miles and are estimated to contain 2,350,000,000,000 tons, or about two-thirds of the total supply.

The productive coal fields of the Pacific coast are principally in the state of Washington, but the output is relatively small, and, as crude oil from California is the principal fuel in that section, they are hardly pertinent to this discussion.

It is estimated that the total original contents of these great coal fields, lying at depths not exceeding 3000 feet from the surface, were something over thirty-five hundred and fifty billion short tons, exclusive of Alaska, from which we have taken, to the close of 1916, about 11,500,000,000 tons, and assuming, as we do, that for every ton of coal produced one-half a ton has been lost, the exhaustion has amounted to 17,250,000,000, or, in other words, in a century of mining we have exhausted just about one-half of one per cent. of the original supply. At the rate of production in 1916, and assuming that we shall continue to lose half a ton for every ton mined, the storehouse still contains enough to last something like four thousand years. It does not look as if the problem were one of supply.

It must be remembered, however, that when we are speaking in these great figures of thousands of billions of tons as the total of our coal supplies, the great bulk of them consists of low-grade bituminous coals, and lignites which are contained in the Gulf, the Great Plains, and the Rocky Mountain provinces. Practically 70 per cent. of the total reserves are in these provinces, all of which are west of the Mississippi River. Only 15 per cent. is represented by the higher grade coals—the anthracite of Pennsylvania and the semi-bituminous and bituminous coals of the Appalachian region, and another 15 per cent. by the medium grade, non-coking coals of the Mississippi Valley states. And moreover, it is upon these higher grade coals, of which we have the least in quantity, that we are making the heaviest drains. Of our total production at the present time, about 70 per cent. is from the anthracite fields of Pennsylvania and the bituminous coals of the Appalachian areas, 20 per cent. is from the states composing the interior province, and less than 10 per cent. from the great fields of the farther West.

Still, when we consider that even in these more rapidly exhausting areas in the East the quantity of coal yet remaining is about a thousand times the drain made upon it in 1916, we can hardly say that the problem is one of supply—certainly not of supply at the source. Even in the anthracite region, comparatively small as it is, and whose annual output to-day is equal to what our total production of coal was in 1881—thirty-five years ago—there still remains 80 per cent. of the supply that was there when mining began. Anthracite, as you all doubtless well know, is now almost entirely a domestic fuel. It had at one time quite a vogue as a blast-furnace fuel, but that has passed. It is still used to some extent in the manufacture of gas and as a locomotive fuel for the first-class passenger trains of the anthracite carrying roads. Otherwise it is hardly known as a fuel except in domestic stoves and ranges and in the heating and operation of office buildings, hotels, and apartments, which is practically domestic use. Probably the first pinch will come in the high-grade semi-bituminous coals, the great bulk of which lies along the eastern border of the Appalachian coal field. They are relatively scarce, representing less than 2 per cent. of our total resources, and it is upon these that the drain is being made at a rapidly in-



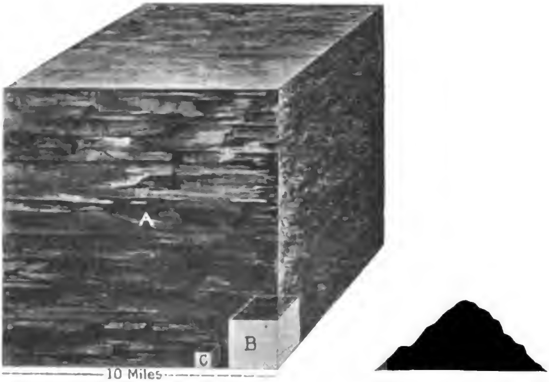
WORLD'S PRODUCTION OF COAL IN 1912

creasing rate. Campbell, of the Geological Survey, in his introductory chapter to a report on the coal fields of the United States says that these will be the first exhausted, and that such exhaustion may occur in the not very distant future. These are our best steaming coals, and their exhaustion will be a greater calamity to the country than the loss of all the anthracite, for coal of this kind has a greater efficiency and is adapted to more diverse uses than anthracite. We are rapidly consuming the cream and leaving the skim milk.

As I have said, practically all of the anthracite, or hard coal, as it is frequently called, which Nature has provided for the use and comfort of the people of the United States is found in a small area (less than 500 square miles) in the northeastern part of Pennsylvania. It has been estimated by geologists that when Nature had completed her task of depositing the coal, the contents of the field were about 16 times more than they were when man first began to mine and use it. These deposits, like those of other coals, passed through the various stages of forest growth, peat formation, lignite or brown coal, and then into bituminous coal. After these came tremendous earth movements by which the beds, formerly nearly horizontal, were bent and folded into mountains and valleys and the bituminous coal was changed to anthracite. The heat, and the pressure which caused it, during this period of stresses drove off the gases contained in the coal (and which produce the smoke when bituminous coal is burned), while the pressure itself compacted the material into the lustrous, dense, hard coal we know as anthracite.

After the mountains and valleys were formed, they were for millions of years subjected to the destructive wear of frosts and cutting streams, and finally were spread over by great glacier flows that came down from the north, so that by far the greater part of the mountains, containing most of the coal, were ground off and washed away until only remnants lying in the bottom of the great folds and containing only about 6 per cent. of the coal originally deposited were left for man to use. Nature seemed to regret her former generosity and took away the greater part of her gift. She was as wasteful as man is when in burning the fuel he gets only from 5 to 10 per cent. of the energy contained in the coal.

The conditions under which the vegetable débris was originally grown and deposited and the heat and pressure to which different parts of the coal region were subjected were not everywhere absolutely the same, and so we find that there are some considerable differences in the qualities of the resultant anthracite. Where the heat and pressure were less the transformation was less complete. In these areas the coals are not so compact and are free-burning, but where Nature's action was stronger the change was more pronounced and the coals are harder and burn out somewhat less rapidly than the free-burning coals. All of them burn without smoke, however; all are clean and nice to handle: all are practically free from dust, and all are absolutely safe in the stove, furnace, or cellar.



A. our coal supply; *B*, total exhaustion; *C*, coal mined last year.

Pike's Peak, 14,108 feet above sea level.

Coal supply of the United States—1000 cubic miles.

Anthracite, as it comes from the mines, is a confused mixture of large and small coal, rock, slate, bone, and dirt, which must pass through an elaborate process of manufacture before it becomes the article of commerce with which the consumer is familiar. The impurities of rock, slate, bone, and dirt must be separated from the coal, and the coal itself must be screened into the various sizes desired by the consumer, the pieces that are too large being broken up and made into marketable sizes. The factories in which this work is accomplished are known as "breakers," although the object is to secure the largest quantities of domestic sizes of clean coal with as little breakage as possible.

The percentages of the different sizes obtained vary somewhat throughout the several districts or regions, according to the character of the coal and the mining conditions, the average for the entire region being approximately, of prepared or domestic sizes (including lump and broken coal), 60 per cent., pea coal 12 per cent., and the smaller, or steam, sizes 28 per cent.

Conditions in the bituminous coal industry are widely different from those that control the production of anthracite. In the first place, the manner of occurrence, and consequently the methods of mining, are not the same. For the most part, the coal beds of the Appalachian and interior provinces lie relatively flat. There has been some movement, and some faulting, as the geologists say, but it has been chiefly in the way of elevation and depression, and none of these fields has been subjected to the same folding action as has occurred in the anthracite region. The mountains and valleys of the Appalachian bituminous fields are due to the influence of cutting streams, and where the coal lies above water level considerable quantities have been carried away, but, compared to the losses in the anthracite region, those in the bituminous fields have been relatively insignificant. In the interior province, where the country is low and flat, the coal beds are below water level and intact, except along the northern and western edges.

The mining problems in the production of bituminous coal are simpler than in the production of anthracite, and there is little or no preparation, the only process of "manufacture" being the passage of the coal over screens that may separate it into three or four sizes, usually three—lump, nut, and slack. And this is by no means general. A large part of the product is sold as mine-run, dumped from the mine cars into the railroad cars.

Bituminous coal is chiefly an industrial fuel—anthracite a domestic fuel. According to the report of the United States Geological Survey, 28 per cent. of the bituminous production is used for railroad fuel, 33 per cent. by the industrial steam trade, 15 per cent. in the manufacture of coke, and 16 per cent. for domestic use and small steam trade. The probability is that, out of the 502,518,682 short tons of bituminous coal produced in 1916, not much more was used for domestic purposes than there was of anthracite, whose total production was 87,578,493 short tons, equivalent to 78,195,262 long tons.

I think I have shown that the great problem with which we are wrestling to-day, the problem of providing enough fuel, is not with the supply at the source. We must look for the trouble somewhere else. In the first place, I suppose it is hardly worth while for me to say that stupendous changes have taken place in the country within the last twelve months. It seems hardly possible to realize at the present moment that little more than a year ago the production of both anthracite and bituminous coal was in excess of the demand. Millions of tons of anthracite were in the storage yards of the big producing companies, and the problem the operators were then trying to solve was that of getting rid of the surplus and of the output that the mines were continuing to produce. Because of interruption to the normal ocean transportation and inability to secure vessels, the terminals of the great railroad systems became congested with freight consigned to the European countries that are now our allies, and cars that should have been engaged in bringing coal to market were tied up under load with no place to discharge. As a consequence of this situation, the coal in the yards of dealers gradually disappeared, as comparatively little fresh coal was coming in to take its place. The scarcity of equipment due to the congestion at tidewater terminals was more seriously felt in the bituminous coal fields than in the anthracite region. Bituminous coal has to be moved from the mines as fast as it is produced. If there are no railroad cars in which to load it, the mines must shut down until a supply of cars is at hand. So, too, if the markets are glutted and there are no buyers, production must stop, or at least be slowed up, until the surplus disappears. The great storage yards of some of the larger anthracite companies serve as an escapement or balance-wheel to that industry, but the bituminous mines are denied it. The difficulties in storing large quantities of bituminous coal vary with the kind of coal. Some of them have a tendency to ignite spontaneously when heaped in large piles, while all of them deteriorate somewhat rapidly on exposure to the atmosphere through the loss of volatile gases. Many kinds of bituminous coal also "slack," producing fine coal that is of inferior quality as fuel. The production of the different sizes or grades of anthracite is at a practically unchanging ratio. The proportions of egg, stove, nut, pea, etc., are about the same, year in and year out, but the market demands vary radically. During the winter season, under normal conditions, the demand for the domestic sizes naturally increases over that of the summer, so that it usually occurs that during the summer months considerable quantities of these sizes go into storage, to be picked up and sent to market when cold weather approaches. It frequently happens that in the winter months the steam sizes are in excess and they go into the storage piles to take the place of the domestic coal shipped out. When the demand for all sizes falls below the ratio of production, the surplus goes to the storage yards, the mines are kept going and the miners are kept employed. It is cheaper in the long run to pay for the extra handling and suffer some loss in degradation than to shut down the mines.

Susquehanna Coal Company, Shamokin Division, Shamokin, Penna. Concrete block house for some of the Cameron Colliery employees.

Now, in the early part of 1916, as I have said, there were some millions of tons, mostly domestic sizes, of anthracite in storage, but this, like the coal in the dealers' yards, gradually disappeared, and then it suddenly dawned upon everybody that there was practically no coal in sight and that the householder, the manufacturer, the public utilities, and the railroads found themselves dependent upon the day-by-day production of the mines. Then came the long, cold winter that necessitated the continued use of coal for household heating purposes fully a month after furnace fires are usually abandoned. This condition was particularly in evidence in the Northwest, and the surplus of several hundred thousand tons of coal that is generally carried over from one year to another was entirely consumed. Moreover, lake navigation was more than a month later than usual in opening up, and the water carrying season has been shortened that much.

That section of the country is, in consequence of this and of other complications in lake traffic, in a much worse condition than other sections of the country that can be reached by all-rail haul in the winter.

Then came the long-deferred, but finally inevitable, entrance of the United States into the world war. Munition plants and other factories which had for two years been working overtime to supply the entente Allies doubled their energies, and the demand for coal and coke increased in proportion. Plants that in normal times were operated eight, or at the most ten, hours a day began working three shifts of eight hours each. I have been told that in the city of Bethlehem the demand for, and employment of, labor has increased so much beyond the places to accommodate them that one bed has been made to serve three shifts for as many men.

Our coal mines have for many years had a capacity for production of about 50 per cent. more than their annual output. That is to say, that in 1915, for instance, when they turned out something over 530,000,000 tons, they could have produced with the same complement of men and with a sufficient supply of cars about 800,000,000 tons, for the average number of days worked was only 209. By working 300 days in the year and eight full hours a day this figure could easily have been attained.

That they have not been able to meet the demand upon them has been due primarily to two causes, the more important of which has been the failure of the railroad companies to perform the extra service such a result demanded. Whether it was due to lack of foresight or whether it was due to causes beyond their control, the result is the same. They have not been able to respond to the call for cars or for the motive power the changed conditions required. Possibly locomotive and car builders have been too busy supplying foreign demand at highly profitable prices to accept orders at the prices which our railroad managers thought they could afford to pay, but, however that may be, the production of coal has been badly handicapped by lack of car supply. Operators have cried "Cars, cars!" but they say there are no cars, and many mines in the bituminous regions have been able to work only three to four days in the week for want of railroad cars. How serious this situation is may be judged from the report of a conference recently held between members of the National Association of Coal Operators and the Fuel Administrator, at which the statement was made that for the ten days prior to the conference the reduction of coal output below capacity had not been less than 400,000 tons per day.

I speak now of bituminous coal, for it is bituminous coal and its product, coke, that are needed for manufacturing fuel. Anthracite has not been subjected to the same untoward conditions. The anthracite carrying roads have more satisfactorily responded to the demands upon them and have transported to market during the first nine months of this year the heaviest tonnage ever produced in the same length of time. The shipments from the anthracite mines from January 1 to September 30 this year have amounted to 57,778,000 tons, exceeding the shipments in the corresponding period in 1916 by 7,850,000 tons and beating the previous high record, made in 1911, by more than 6,400,000 tons.

The question then naturally arises, Why, if the anthracite mines have produced such a greatly increased quantity this year, is there such a general shortage of coal through the anthracite consuming territory? I am not going to say that this shortage is psychological, but I do believe that there is more coal in the cellars of consumers to-day than ever there has been before in the history of the country. The trouble has been in the distribution, not by the mining companies nor the railroads, but to consumers. The available supply of coal for the coming winter is concentrated in comparatively few cellars. During the spring and summer of this year the anthracite operators, through their publicity organization, advised consumers to take warning from the experience of 1916 and to lay in their supplies early in the summer, and, in order to stimulate early buying, put into effect the customary spring and summer discounts, though they were convinced—and events have since proved—that all of the coal could have been sold at full circular price. Undoubtedly, most of those who could afford to, and who were forehanded, took good advice, and their cellars are stocked with a winter's supply, but also undoubtedly, and very unfortunately, the people of less means—and they are the more numerous—were misled by newspaper reports that when the government got in its work on the coal operators, coal carriers, and coal dealers there was going to be a great slashing of coal prices. Small consumers only had to wait and they would effect a material saving on their coal bills. Well, the Federal Trade Commission made a pretty exhaustive inquiry into the anthracite situation, with the result that when the President, on

August 23, announced the mine prices for anthracite, he practically adopted the Reading circular. The Federal Trade Commission not only investigated mine costs and prices; it also investigated and is still investigating the costs and profits in the conduct of the retail coal business. It found, it is true, that in some cases dealers had been exacting unreasonable profits, but the business as a whole was not doing injury or injustice to the public, and there has been no general slashing in the retail prices of anthracite. It was largely the poorer classes that were misled by these reports, and it is they unfortunately that point the modern moral of a certain parable with which you are all familiar—their lamps, otherwise their coal bins, are unfilled. I am optimistic, however, and believe that we will get through this winter without much suffering, even among the poorer classes. Those who have their cellars full will not have to buy any more, or at least will have to buy very little coal, to see them through. As I have said before, more attention is being paid just now to the Northwest, in order that as much coal as possible may be sent to that section before lake navigation is closed by ice. After that pressure is removed, greater consideration can be given to the more southerly markets, and they will to a large extent be taken care of.

Concrete City, Delaware, Lackawanna and Western Railroad.

And let me here speak for a moment of the manner in which the anthracite production has been distributed from the mines.

The Anthracite Bureau of Information, maintained at Wilkes-Barre by the anthracite producing companies, and with which for the past two years I have been connected, has compiled some statistics of the distribution of the output in the last two years to four leading markets—New England, New York City, Philadelphia, and the lake ports of Buffalo and Erie. These statistics show that the shipments to New England for the first eight months in 1916 were 5,790,237 tons; this year they have amounted to 6,455,941 tons, the increase being 665,704 tons, or 11.5 per cent. The shipments to New York have increased from 12,666,650 tons to 13,912,384 tons, a gain of 1,245,734 tons, or a little less than 10 per cent., while to Philadelphia were sent, in 1916, 4,186,698 tons, and in 1917, 4,927,992 tons, the increase being 741,294 tons, or 17.7 per cent. On the whole, it can hardly be said that Philadelphia has any just cause for complaint. The lake ports had not fared so well, but even there there is no actual diminution in shipments, and by the time the lakes are closed it is believed that even the shortage due to the unusual consumption in the spring months will have been more than made up. I think the showing regarding the distribution to these markets is quite convincing that the increase of 16 per cent. has been equitably distributed.

Anthracite, as I have said, is now almost exclusively a domestic fuel, the relatively small amounts consumed by railroads and gas companies not being important factors under normal conditions, but, owing to the inability of the bituminous mines and the coke ovens to meet the demands put upon them by the manufacturing industries of the country, extra demands have been made upon the anthracite mines. In some cases powerful influences have been brought to bear seeking to compel the anthracite interests to divert their product from its legitimate and customary channels, in order to relieve conditions that have developed chiefly through the failure of the transportation companies to supply the needed cars to the soft coal mines, and not the least of the difficulties with which the operators are contending at the present time is the protection of their regular trade.

The entrance of the United States into the world war has placed additional obligations upon the operators of coal mines, both anthracite and bituminous. The munition and other plants that, while the United States was still a neutral, were manufacturing war materials for the Allies now have a preferred place in the distribution of coal, because they are making the guns, the shells, the ammunition, the clothes, and other equipment for our own army and navy. They cannot be allowed to shut down; they must be provided with fuel. And then the government itself has become a very important purchaser and consumer of coal, and its demands have absolutely first call upon the output of the mines. The forts and cantonments in which our national army is being concentrated and trained must be kept constantly supplied with the coal necessary for heat and cooking. The demands from these are principally for anthracite, and to give you an idea of what this amounts to, I may state that the requirements of one of these cantonments alone for the month of November amounted to nearly 12,000 tons. The Navy Department also required considerable quantities of anthracite, though its principal demands are for bituminous coal; in fact, while the anthracite tonnage required for all the government departments may be stated in thousands or hundreds of thousands, the demands for bituminous coal will run into the millions.

Concrete City house.

Even Nature seems to be determined to add to the demands made at this particular time upon the mines, as if their burden was not already sufficient. I refer to a condition that has developed in Ohio and which should be relieved if possible. The failure of the natural gas supply is a serious matter to the people in that section. Most of the homes in the country and in the smaller towns are equipped with base-burning stoves, in which anthracite or natural gas can be used, but which are not adapted to the use of bituminous coal. And from them has come a Macedonian cry it is impossible not to heed. With the supply of natural gas cut off, unless the people can secure anthracite, it means the discarding of their base-burning stoves and the substitution of bituminous coal burning stoves to an extent which the stove dealers and manufacturers are not prepared to supply. It presents one of the most serious phases of the problem of coal supply.

The labor situation is another serious phase of the problem. Attracted by the higher wages being offered by munition and other manufacturing establishments, men have deserted the coal mines by the thousands. The call for men for the army and navy has taken other thousands from the mines. The average number of men employed in the anthracite mines under normal conditions is from 175,000 to 180,000. Reports to the Anthracite Bureau of Information show that the average for the last few months has been only a little more than 150,000 men. This means a shortage of nearly 25,000 mine workers, and yet in two recent months, June and August, the shipments have exceeded 7,000,000 tons, the only two instances in the history of the region —a really remarkable record. It is well, however, to sound a note of warning. The anthracite mines are at the maximum of their capacity. Any further depletion of the labor must result in a decreased output, and the problem will not be one of coal supply but of getting along with less. That may not be impossible. We have been accustomed to a bountiful supply, and at prices less than the people of other countries pay for their fuel. We have been profligate in its use, and it is now time to undertake a reform. You who are still living at home and not in a hotel or apartment may do your bit in helping to solve the problem of coal supply. The heating of your home should be brought down to a practical basis of efficiency. You should ask yourself whether or not you are getting a dollar's worth of heat for every dollar's worth of fuel you consume. Probably you are not. The fault may be with your stove or furnace or with the kind of fuel you are using, or with your method of regulating the stove or furnace. Quite frequently that same faithful old stove or furnace is unjustly blamed, and it is in reality the method of regulation that is at fault.

Sometimes the combustion chamber is not sufficiently filled, or it may be too full. The top of the fire-brick linings in the range, cylinder stove, or hot-air furnace and the bottom of the feed-door opening into steam and hot-water boilers are the definite gauges by which you should judge the height of the fuel bed. Always fill the fuel space of your stove, furnace, or boiler accordingly, heaping the coal slightly in the centre. The fuel space should be filled twice a day in winter weather. The last time should be as late at night as is convenient. By feeding small quantities of anthracite to the fire several times a day, with attendant shakings, you lose in both economy and comfort. Shake the grate only until a bright light shows underneath, and do this only twice a day. Further shakings permit unconsumed coal to pass through the grate-bars. When the furnace is filled at night the fire should be checked or damped down and be ready to give a quick heat in the morning. Steam or hot-water boilers should have the fireplace filled with coal at least to a point level with the bottom of the feed-door opening, and one feeding should be sufficient for twelve hours if the drafts are properly adjusted. Once in the morning and once in the evening are the only times when attention is necessary under normal weather conditions. Ashes should be shaken down just before the furnace or stove is refilled with fresh coal. Keep the ash-pit empty. Do not let the ashes bank up under the grate. This not only prevents the proper circulation of air needed for combustion, but also tends to warp the grate-bars. Removing the ashes regularly once a day, even if only a small amount has fallen, is the best plan.

Efficient management of domestic stoves and furnaces will go far toward solving the problem of domestic fuel supply.

OCCLUDED GASES IN FERROUS ALLOYS.*

BY

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In view of all the elaborate and careful researches which have been conducted during the last forty years on the subject of occluded gases, some apology seems necessary for further work on this subject. From a careful search of the literature, the following observations in reference to previous work seem to be justified:

First.—The containing vessels used were porous in most cases—especially at high temperatures.

Second.—When gas flames were employed as a source of heat, the partial diffusion of such gases through the tubes added an additional error.

Third.—Practically all of the temperatures heretofore obtained were not sufficient to completely expel all of the occluded gases.

One of us (Alleman), in conjunction with C. Heyburn Jones, attempted some preliminary experiments, hoping to secure materials for containers which would not be open to the objections just indicated. This work was started in February, 1914.

Interest in occluded gases was aroused by an investigation one of us (Alleman) conducted, which had to deal with the bubbles formed around wire in wire glass. This was undertaken about four years ago. For a long time we were of the opinion that these bubbles were composed of carbon dioxide and emanated from the glass itself, the wire simply acting as the nucleus for the formation of the gas. While working at the plant and observing the glass plates as soon as the wire had been rolled into them we were impressed with the fact that the gas did not appear next to the wire until after the wire had been in contact with the molten glass for several seconds. After this space of time, the wire suddenly brightened as if some chemical action had taken place, and bubbles immediately appeared on the surface of the wire. When glass was rolled at very low temperatures it was noticed that the amount of gas around the wire was not as large as when the glass was rolled at higher temperatures. It was also noticed that various wires were responsible for the production of more or less gas, and wires made of certain metals, notably platinum, copper, and nickel, when rolled into molten glass were almost free from this phenomenon.

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* Concluded from page 357, vol. 185, March, 1918.

[1] We acknowledge, with appreciation, the assistance rendered by Mr. W. R. Gawthrop, of this laboratory.

The preliminary experiment which indicated that the wires occluded gases, and that these gases were given off in heating, consisted of a simple test with a glass tube and a piece of wire. The wire was inserted into the glass tube, one end sealed in, and the other, open end, attached to a vacuum pump. A vacuum was applied to this tube, and the tube heated by means of a Bunsen burner. The tube soon collapsed, and the wire was firmly imbedded in the glass. Under these conditions—namely, when the tube was under a vacuum—no bubbles appeared between the wire and the glass; whereas, when a similar tube was heated, but not subjected to the influence of a vacuum, bubbles appeared between the glass and the wire.

We wish to acknowledge the many courtesies extended to us by Mr. Walter Cox, president of the Pennsylvania Wire Glass Company, who furnished us with materials and granted opportunities for observation without which we should have been unable to continue this work

After the above-named investigation was completed, we determined to investigate the question of occluded gases in a more scientific manner than the limits of a technical research would permit.

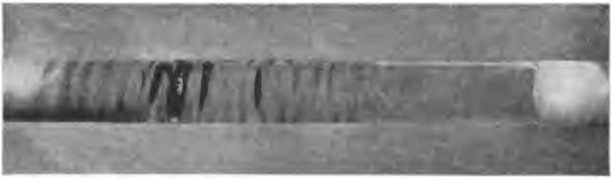
Hard-glass tubes were first employed, but it was soon found that no glass known would withstand the temperatures required without melting. Porcelain tubes were next tried, but these became porous, evolved gases, and added additional complications to the subject. Tubes made of certain alloys were rejected for the same reason.

Quartz tubes were next employed, and these were jacketed and a vacuum placed on the outside as well as the inside of the tube.

It was determined that quartz was unfit for our experiments, because clear quartz vitrified at about 1100° C., and was found to be very porous at this temperature. In this connection we wish to detail an experience and to exhibit a picture of the actual tube employed. A quartz tube was wound with nichrome ribbon, surrounded with an iron jacket, a vacum pumped on the iron jacket and also on the quartz tube, and the tube heated (by passing a current through the nichrome ribbon) to about 1000° C. The tube contained no material, but gas was evolved from the tube, and this proved to be composed largely of hydrogen and carbon monoxide. The results obtained follow:

Gas	Analysis No. 1, 15 hours c.c.	Analysis No. 1, 15 hours %	Analysis No. 2, 63 hours c.c.	Analysis No. 2, 63 hours %	Total c.c.	Total %
Illuminating	0.0	0.0	0.0	0.0	0.0	0.0
CO_2	0.0	0.0	0.0	0.0	0.0	0.0
CO	.6	4.41	7.6	29.9	8.2	21.01
O_2	0.0	0.0	0.0	0.0	0.0	0.0
H_2	5.64	41.50	12.2	48.0	17.84	45.75
N_2	7.36	54.09	5.6	22.1	12.96	33.24
Total	13.60	100.00	25.4	100.0	39.0	100.00

FIG. 1.



Illustrating porosity of quartz at 1000° C. Quartz tube showing spiral of carbon in inside (dark line). This tube was wound with nichrome ribbon on the *outside*. The deposit of carbon was formed on the *inside* by the oxides of carbon, occluded by the nichrome ribbon, passing through the walls of the heated quartz tube, and their probable dissociation, to some extent. Tests for traces of chromium and nickel were negative.

The source of this gas could not be imagined at first, as it is improbable that quartz contains either hydrogen or carbon monoxide. The tube was removed from the furnace and examined. On the inside of the quartz tube, under the spiral made by the nichrome ribbon, a deposit of carbon was found (see Fig. 1). It is apparent that at a temperature of 1000° C. quartz is quite porous; that carbon monoxide or carbon dioxide passed through the walls of the tube; that probably either or both of these gases dissociated to a slight extent, and that carbon was deposited. This gas must have been occluded by the nichrome ribbon.

This difficulty was not experienced, so far as carbon is concerned, when quartz tubes were wound with platinum wire. Under the conditions of an external and internal vacuum, however, it was found that platinum was somewhat volatile, and the temperature of the quartz could not be raised to such a degree as to evolve all of the gas contained in the iron without completely devitrifying the quartz. Although a number of experiments were carried out with quartz tubes, they were finally abandoned and special alundum tubes substituted. The results of the experiments with both kinds of tubes are given below.

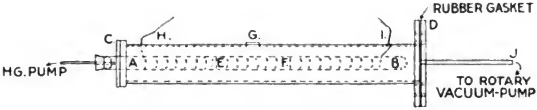
It was impossible to secure alundum tubes which were impervious to gases at temperatures above 1000° C., but by means of alundum cement the porosity of these tubes was markedly decreased. The special alundum tubes were wound, placed inside an iron jacket, a partial vacuum (740 mm.) placed on the iron jacket, but a complete vacuum (nearly 760 mm.) maintained on the inner alundum tube before heating.

Desiring to secure higher temperatures than platinum resistances would afford, molybdenum wire was secured and used for our resistance. It will be remembered that molybdenum has a melting-point of about 2500° C., but that it readily oxidizes in contact with air. By means of this apparatus temperatures of 1900° C. were reached, which were sufficiently high for all purposes. It is believed that this apparatus furnishes a means of research in connection with the subject of occluded gases which is not open to the criticisms previously referred to.

A description will be given of several of the forms of apparatus used, and some typical results obtained by the use of each. It will be observed that the distinctive feature of all these furnaces consists in the fact that each heating tube is enclosed by a jacket, and, while a partial vacuum is maintained on the outside jacket, a vacuum, as complete as possible, is maintained on the inside tube. One of the first forms of apparatus used is shown in Fig. 2.

AB is a glazed quartz tube, 24 inches long and 1 inch in external diameter. It is closed at the end *B*, and contains 6 inches of transparent quartz in the middle, *EF*, in order that the sample may be observed during heating. The quartz tube is surrounded by a 3-inch iron pipe, *CD*, containing a window, *G*, formed by boring a 1-inch hole directly above the transparent portion of the quartz tube. This hole is closed by a piece of glass, air-tight connections being made here as elsewhere by the use of bakelite cement. The quartz tube is wrapped with 6 to 8 feet of nichrome ribbon, having a resistance of 1.4 ohms per foot. This ribbon was previously heated in a vacuum in order to expel any gases occluded in it. The leads pass through the iron pipe at the points *H* and *I*. The outside chamber is connected to a rotary vacuum pump at *J*, and the inside chamber is connected to a mercury vacuum pump at *A*. Since the quartz tube extends several inches beyond the iron tube at this point, a rubber stopper is used as a connection without there being any danger of its burning. As a further protection, the end of the tube is water-cooled. The temperatures are read through the window, *G*, by means of a Wanner optical pyrometer.

Fig. 2.



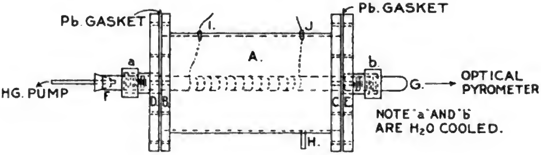
Weight of wire in grammes	Time of heat in hours	Volume of gas in cubic centimetres	Percentage composition of gas			
			CO	O_2	H_2	N_2
16.0362	3.0	31	5.48	0	48.15	46.37
13.7347	4.5	22.6	11.76	0	28.00	60.24
14.6718	5.0	26.7	16.40	0	51.60	22.00
11.3470	30.0	79.0	9.80	0	65.90	24.30
13.5516	6.5	26.2	19.85	0	41.90	38.25

By the use of this apparatus several experiments were conducted with iron wire at temperatures ranging from 900° to 1000° C.

It can be seen that the ratio of the volume of hydrogen obtained to the volume of the metal used varied from 3 to 30, depending upon the time of heating. In every case hydrogen was the largest constituent of the gas. This fact seemed to corroborate the statements of several of the earlier experimenters, who, it will be remembered, stated that, up to a low red heat, the gas evolved consisted mostly of hydrogen.

It developed that this type of apparatus was not suitable. No heat-insulating material could be placed between the outside and the inside tubes without closing the window. The outside tube became so hot, even at 900° C., that the connections could not be kept tight. The glass window cracked and caused continual leaking. Owing to the relatively small diameter of the outside iron jacket of the apparatus, there was not sufficient room to work inside the apparatus, and great difficulty was experienced in making connections. To obviate these drawbacks, a new type of apparatus was next designed and used. It is detailed in Fig. 3.

FIG. 3.



A is an iron pipe, 8 inches in diameter and 13 inches long. The flanges *B* and *C* are screwed to each end. To *B* and *C* the flanges *D* and *E* are bolted, air-tight connections being made by means of lead gaskets. These blind flanges *D* and *E* are bored through the middle, and into the holes are inserted 1½-inch nipples, on which are screwed caps containing 1-inch holes to permit of the insertion of the quartz tube *FG*. The nipples and caps are used in order to remove the packing for the air-tight connections as far as possible from the heating element, and also to give space for a water-cooling device. Various materials for the air-tight connections were investigated to determine whether or not any were better for this purpose than bakelite, the latter being difficult to remove if any necessity arises for opening the furnace. Red lead and glycerine, Johns-Manville cement, okonite tape, and alundum cement were investigated. The best results are obtained by the use of bakelite cement at one end and a combination of a rubber stopper and okonite tape, covered with a layer of bakelite varnish, at the other end. All connections are covered with several layers of bakelite varnish. The quartz tube *FG* contains a transparent section 3 inches long at the end *G*. This arrangement possesses an advantage over the former one in that, in this case, it is possible to read the temperatures inside the tube, whereas before only the temperatures of the surrounding resistance wire could be read. In this case some insulating material can be placed in the space between the two tubes. A heating element of 20 feet of No. 22 platinum wire is wrapped around the middle of the tube for about 9 inches. Connections are made with the outside 110-volt, direct-current terminals, at the points *I* and *J*, in the manner illustrated.

The outer tube is connected to the rotary vacuum pump through *H*, and the quartz tube is connected to the mercury vacuum pump as in the previous apparatus. To serve as heat insulation, two or three layers of asbestos rope are wrapped around the quartz tube outside of the platinum wire.

In order that the test samples might be of very accurately determined composition, standard samples of iron and steel of varying percentages of carbon were obtained from the United States Bureau of Standards.

In the first determination 8.6604 grammes of basic open-hearth steel containing 1 per cent. carbon was used. The analysis of this steel, as furnished by the United States Bureau of Standards, is as follows:

Carbon	1.049
Silicon	.153
Phosphorus	.045
Sulphur	.028
Manganese	.405

DETERMINATION NO. 1.

Basic Open-hearth Steel—1.0 per cent. Carbon. Weight—8.6604 Grammes.

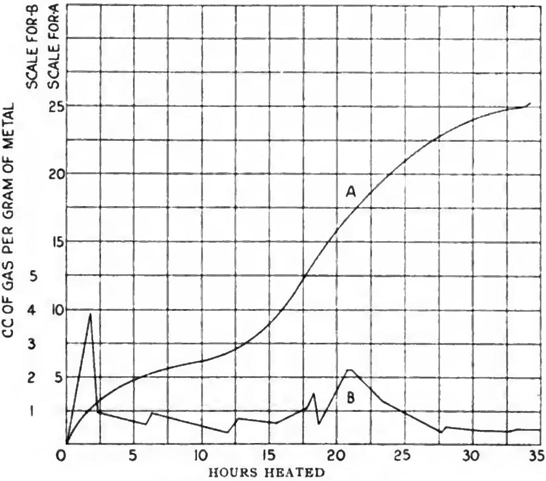
Hours heated	Gain in hours	Total gas, c.c.	C.c. gas per gramme	Gain in c.c.	Rate in c.c. per hour	Rate in c.c. per gramme per hour
1.75	1.75	25.2	2.91	25.2	14.4	1.661
2.25	.50	28.4	3.28	3.2	6.4	.739
5.75	3.50	40.7	4.7	12.3	3.52	.406
6.25	.50	43.8	5.06	3.1	6.2	.716
11.75	5.50	58.8	6.79	15.0	2.73	.315
12.75	1.00	65.8	7.59	7.0	7.0	.809
15.75	3.00	82.4	9.50	16.6	5.53	.639
17.75	2.00	99.2	11.44	16.8	8.4	.970
18.50	.75	108.4	12.52	9.2	12.25	1.415
19.75	1.25	114.6	13.21	6.2	4.96	.572
21.00	1.25	138.0	15.93	23.4	18.70	2.160
21.50	.50	147.2	17.00	9.2	18.40	2.120
23.50	2.00	169.6	19.55	22.4	11.20	1.292
25.75	2.25	183.0	21.13	13.4	5.95	.686
26.50	.75	186.8	21.55	3.8	5.07	.585
27.25	.75	195.8	22.60	9.0	12.00	1.385
27.75	.50	197.4	22.79	1.6	3.2	.3695
28.25	.50	199.8	23.04	2.4	4.8	.544
28.75	.50	202.2	23.35	2.4	4.8	.554
29.75	1.00	205.8	23.75	3.6	3.6	.416
30.75	1.00	208.3	24.05	2.5	2.5	.2885
31.75	1.00	210.4	24.30	2.1	2.1	.2425
32.75	1.00	212.6	24.55	2.2	2.2	.254
33.75	1.00	215.4	24.85	2.8	2.8	.323
34.75	1.00	218.0	25.17	2.6	2.6	.300

8.6604 grammes of this steel was placed in a platinum boat and heated. The variations in the rate of evolution of the gas are shown in the table and in the curves (p. 469). The gas obtained was collected and analyzed at six different stages. The results of these analyses are as follows:

Cubic centimetres gas	Time, hours	Temperature, ° C.	Analysis of the gas collected, per cent.				
			CO_2	O_2	CO	H_2	N_2
28.4	2.25	940	0.0	2.82	50	21.5	24.68
15.4	4.0	1046	1.52	4.0	48	31.0	15.75
		1242					
38.6	9.5	1332	0.0	3.88	58	23.7	14.22
64.8	5.75	1452	Analysis	not made	—gas escaped.		
22.4	2.0	1452	0.0	0.0	89.5	3.32	7.08
		1438					
48.4	11.25	1468	0.0	3.72	60.5	14.9	20.88
218.0	34.75		0.13	2.08	59.8	18.18	19.81

We thus find that over the space of 35 hours during which the metal was heated, 218 c.c. of gas, or 25.2 c.c. of gas per gramme of metal, or about 198 c.c. of gas per c.c. of metal, was evolved. Sixty per cent. of this gas was carbon monoxide. When the heating of the metal ceased, gas was still being evolved, but very slowly. Heating was stopped on account of the failure of the quartz tube, which had become devitrified at the high temperature attained and had cracked. It was also discovered that the platinum boat, which contained the metal, had been attacked, the bottom being entirely destroyed. A considerable amount of carbon was found to have been deposited on the inner portion of the tube during the determination. It was concluded that this carbon was due to the decomposition of carbon monoxide, and that oxygen might be accounted for in the same manner.

Determination No. 1.



A. Cubic centimetres of gas per gramme of metal.
B. Cubic centimetres of gas per gramme of metal per hour.

Another interesting observation during the course of this determination was noted in connection with the behavior of the platinum wire used as a heating element. When the quartz tube was removed from the outer iron shell it was found to be covered with a fine layer of glistening particles of platinum. Probably the presence of this platinum was due to the platinum volatilizing to a certain extent, a portion of the metal being condensed on the tube. This hypothesis is strengthened by the fact that, as the heating progressed, the amount of the resistance placed in series with the platinum wire, in order to provide a means for regulating the temperature, had to be diminished gradually, in order to maintain a constant temperature. Such would be the case if the diameter of the wire was being diminished by volatilization.

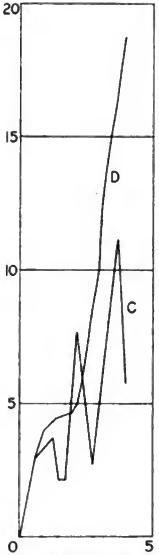
An effort was made to obtain a duplicate of the results of the experiment just described. 5.3247 grammes of the same steel was placed in a quartz boat and heated in a new quartz tube. Since it had been observed that raising the temperature of the furnace tended to increase the rate of evolution of the gas, the temperature of this determination was raised as rapidly as possible to about 1500° C., even though it was known that this temperature would destroy the tube in a few hours. The temperature became too high, however, and at the end of four hours' heating the platinum resistance wire burned out. At that time the temperature inside the tube was about 1500° C. It is well known that platinum melts at about 1755° C.

DETERMINATION NO. 2.

Hours heated	Gain in hours	Total gas, c.c.	C.c. gas per gramme	Gain in c.c.	Rate in c.c. per hour	Rate in c.c. per gramme per hour
0.75	.75	12	2.255	12	16	3.004
1.083	.333	17.6	3.307	5.6	16.8	3.155
1.25	.166	20.8	3.91	3.20	19.2	3.606
1.50	.25	22.2	4.168	1.4	5.6	1.051
1.75	.25	23.6	4.435	1.4	5.6	1.051
2.00	.25	26.4	4.96	2.8	11.2	2.083
2.25	.25	36.6	6.87	10.2	40.8	7.665
2.75	.50	44.0	8.26	7.4	14.8	2.778
3.00	.25	53.0	9.96	9.0	36.0	6.76
3.25	.25	67.8	12.71	14.8	59.2	11.12
3.50	.25	81.6	15.31	13.8	45.2	8.50
3.75	.25	91.2	17.12	9.6	38.4	7.215
4.00	.25	99.0	18.59	7.8	31.2	5.86

The curve shows the rate at which the gas was evolved. The two curves are interesting for purposes of comparison with the curves obtained from Determination No. 1. In this comparison the large increase in the rate of the evolution of the gas with an increase in temperature is especially worthy of note. The gas was collected and analyzed in two lots. The results of the analyses are as follows:

DETERMINATION NO. 2.



C. Cubic centimetres per gramme of metal per hour.
D. Cubic centimetres per gramme of metal.

Determination	Cubic centimetres gas	Time, hours	Temperature, ° C.	CO_2	O_2	CO	H_2	N_2
No. 1.....	36.6	2.25	875 1485	0	0	67.7	16.81	15.49
No. 2.....	62.4	1.75	1470	1.92	0	86.9	8.61	2.57
Total...	99.0	4.00		1.20	0	79.8	11.65	7.35

When the tube was opened it was discovered that the steel had been completely fused, thus showing that a considerable amount of time must be allowed for complete evolution of the gas, even after fusion.

From the figures given it is seen that, up to the time of the burning out of the platinum-wound furnace, the steel had evolved 99 c.c. of gas, or 18.59 c.c. of gas per gramme of metal, equalling about 130 c.c. of gas per c.c. of metal. Of this gas about 80 per cent. consisted of carbon monoxide, as compared with 60 per cent. of carbon monoxide obtained in the former experiment with the same steel.

The weight of the gas obtained was then compared with the loss in weight of the steel and of the quartz boat. The results are as follows:

	Grammes
Weight of the gas obtained	0.111239
Weight of the O_2 in the gas	.05327
Loss of weight of boat and steel	.0720
Loss of weight of boat	.0659
Loss of weight of steel	.0061

From these figures it appears that a reaction had taken place between the steel and the boat, since the loss in the weight of the boat was apparently ten times the loss in the weight of the steel. That such a reaction had occurred was proved by the fact that the bottom of the steel, where it had come in contact with the boat, contained a thin layer of a compound different from either the steel or the quartz. This layer probably consisted of a silicide of iron. By calculating the weight of the gas obtained and then subtracting the weight of the oxygen, both free and combined, in the gas, we obtain a weight which is less than the loss in weight of the steel plus the quartz boat. It would have been possible for the oxygen to have come either from the tube or from the air, due to a small leak in the tube, the outside vacuum having been broken several times during the course of the investigation.

The next determination (No. 3) was conducted on some Bessemer steel of the following composition:

	Per cent.
Carbon	0.084
Silicon	.005
Phosphorus	.094
Sulphur	.082
Manganese	.536

5.2364 grammes of the above steel was placed in the same quartz boat as was used in Determination No. 2, and the heating was conducted as in the previous cases. Since the quartz tube used in Determination No. 2 had become very badly devitrified, due to the high temperature, it was decided that, in this experiment, the temperature should be kept constant at 1100° C., a temperature at which devitrification takes place very slowly. The tables and curves following show the results obtained after heating the sample of Bessemer steel for 23 hours in a new tube. It can be seen, from the figures given, that the 5.2364 grammes of steel evolved 44.4 c.c. of gas, or 8.5 c.c. of gas per gramme of metal, equalling about 55 c.c. of gas per c.c. of metal. Gas was still being evolved, however, when the heating was interrupted. This gas was analyzed as a composite sample, the results of the analysis being as follows:

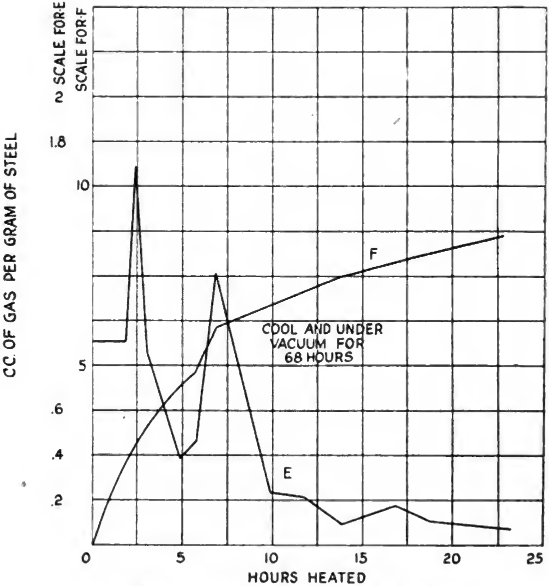
DETERMINATION No. 3.

Hours heated	Gain in hours	Total gas c.c.	C.c. gas per gramme	Gain in c.c.	Rate in c.c. per hour	Rate in c.c per gramme per hour
2.0	2.0	9.6	1.835	9.6	4.8	.917
2.5	.5	14.0	2.075	4.4	8.8	1.680
3.25	.75	17.4	3.32	3.4	4.54	.867
4.0	.75	20.0	3.82	2.6	3.47	.664
5.0	1.0	22.1	4.23	2.1	2.1	.401
6.0	1.0	24.6	4.70	2.5	2.5	.478
7.0	1.0	31.0	5.93	6.4	6.4	1.220
10.0	3.0	34.8	6.65	3.8	1.27	.242
12.0	2.0	37.2	7.11	2.4	1.2	.229
14.0	2.0	38.3	7.31	1.1	.55	.105
17.0	3.0	41.4	7.91	3.1	1.03	.197
19.0	2.0	42.7	8.18	1.3	.65	.124
23.0	4.0	44.4	8.49	1.7	.425	.0814

Cubic centimetres	Time, hours	Temperature, ° C.	CO_2	O_2	CO	H_2	N_2
44.4	23	1100	.68	1.57	26.15	43.40	28.20

It is seen that the gas evolved from this Bessemer steel at 1100° C. consists largely of hydrogen. In this case large amounts of carbon were found adhered to the inner portions of the tube, showing that some of the oxides of carbon had been dissociated. Even though the temperature had not been permitted to rise above 1100° C., it was discovered that the fine particles of steel were slightly fused to a solid, irregular mass.

DETERMINATION NO. 3.



E. Cubic centimetres of gas per gramme of steel per hour.
F. Cubic centimetres of gas per gramme of steel.

DETERMINATION NO. 4.

Another determination was then conducted on the same Bessemer steel (0.1 per cent. carbon). 5.9498 grammes of the steel was heated to approximately 1100° C. for 356.5 hours. During this time 319.3 c.c. of gas was evolved, which was found to be composed as follows:

	Analysis No. 1, 47 hours		Analysis No. 2, 118 hours		Analysis No. 3, 198 hours	
Gas	C.c. gas	Per cent.	C.c. gas	Per cent.	C c. gas	Per cent.
Illuminating	0.0	0.0	0.0	0.0	0.0	0.0
CO_2	.2	.33	.2	.47	.4	.88
O_2	1.0	1.66	.6	1.42	2.6	5.74
CO	16.0	26.68	8.3	20.40	7.6	17.20
H_2	26.1	43.50	26.9	63.70	17.35	38.30
N_2	16.7	27.83	6.2	14.01	17.25	37.88
Total	60.0	100.00	42.2	100.00	43.40	100.00

	Analysis No. 4, 214 hours		Analysis No. 5, 293 hours		Analysis No. 6, 356.5 hours	
Gas	C.c. gas	Per cent.	C.c. gas	Per cent.	C.c. gas	Per cent.
Illuminating	0.0	0.0	0.0	0.0	0.0	0.0
CO_2	0.0	0.0	2.0	3.34	0.0	0.0
O_2	1.1	5.12	4.50	7.52	14.0	15.45
CO	3.4	15.80	8.20	13.70	Analysis not made	
H_2	6.61	30.75	7.64	12.75	Analysis not made	
N_2	10.39	48.33	37.46	62.69	Analysis not made	
Total	21.50	100.00	59.80	100.00	90.4	

Totals of All Six Analyses.

Gas	C.c. gas	Per cent.	
Illuminating	0.0	0.0	Analyses No. 1 to No. 6 inclusive
CO_2	2.8	.88	Analyses No. 1 to No. 6 inclusive
O_2	9.8	3.07	Analyses No. 1 to No. 6 inclusive
CO	43.7	19.09	Analyses No. 1 to No. 5 inclusive
H_2	84.60	39.93	Analyses No. 1 to No. 5 inclusive
N_2	88.00	38.42	Analyses No. 1 to No. 5 inclusive

Total—228.9 + 90.4 = 319.3

It will be observed that 90.4 c.c. of Analysis No. 6 was lost immediately after the oxygen determination had been made, and that, therefore, the remaining constituents of this gas are not known. From the figures obtained in Determination No. 4 it appears that the percentage of nitrogen evolved increased gradually with the time of heating. This fact seemed to indicate that there was possibly a leak in the apparatus. The amount of oxygen present as oxygen, as carbon monoxide, and as carbon dioxide was calculated for each analysis, and was compared with the amount of nitrogen present. The results of these comparisons follow:

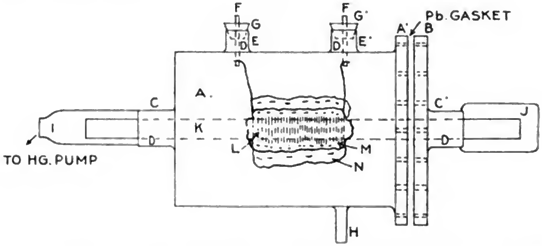
Analysis	No. 1	No. 2	No. 3	No. 4	No. 5	No. 6
Oxygen	35.5	44.4	28.5	21.2	19	....
Nitrogen	64.5	55.6	71.5	78.8	81	....

From these figures it can be seen that the oxygen and nitrogen were present in the latter analyses in almost the same proportion as in air. This fact suggested that the quartz tube was becoming porous with continued heating, and that some of the carbon monoxide and carbon dioxide present in the evolved gas was probably being formed by the combustion of the carbon in the steel.

From the evidence outlined above, as well as from a consideration of other experiments not here described, we arrived at the conclusion that nichrome ribbon could not be used for heating purposes, in consequence of the fact that it contained large amounts of occluded gases and had a relatively low melting-point (about 1100° C.); that quartz was not available, because it devitrified at about 1100° C. and became quite porous; and that while platinum, after being heated in a vacuum, occluded practically no gas, its melting-point precluded its use for the maintenance of temperatures such as we required.

This necessitated the use of another material as resistance for heating purposes, and a tube and container which would withstand higher temperatures.

Fig. 4.



It was known that alundum would withstand much higher temperatures than quartz, and specially glazed tubes of this material were substituted for those of quartz. For a heating element molybdenum, with a melting-point of about 2500° C., was selected.

An important change was made in the iron shell surrounding the outside vacuum space. In the new apparatus all joints possible were welded, instead of being merely screwed together as in the previous apparatus. By this means sources of leaks were minimized. This apparatus is shown in the illustration above (Fig. 4).

A is an iron pipe, 8 inches in diameter and 10 inches long, on one end of which is welded the 2-inch nipple *C*, and on the other end the flange *A'*, to which is bolted the blank flange *B*, containing the nipple *C'*, which is identical with *C*. *E* and *E'* are 1¼-inch pipes, 1½ inches long, welded to *A*, and serving as openings through which to make connection between the heating element and the outside current. *F* and *F′* are iron bolts held in place by alundum cement *D* and by the rubber stoppers *G* and *G′*, on the outside of which are layers of bakelite and rubber cement. *H* is a ½-inch pipe, 1½ inches long, welded to *A* and serving as a connection to the rotary vacuum pump. *K* is the special alundum tube, 1 inch in internal diameter and 24 inches long. It is held in place at *C* and *C′* by the alundum cement *D*, on the outside of which is a coating of okonite tape and rubber cement. The heating element consists of 20 feet of No. 20 molybdenum wire *L*, which is wrapped around the middle of the alundum tube for 5 inches. This wire is connected through *F* and *F′* to the 220-volt, alternating-current circuit. On the outside of the wire is plastered a layer of alundum cement *M*, and on top of this are wrapped a couple of layers of asbestos rope *N*.

It being impossible to obtain gas-tight alundum tubes, even after having them glazed, it was necessary to make the outer vacuum space of the apparatus gas-tight, an operation which proved very difficult. Only after the protruding ends of the alundum tube had been inclosed in the glass coverings *I* and *J* were the leaks finally stopped. It was absolutely necessary that the apparatus should not leak before the current was turned on, as the molybdenum wire oxidized at red heat in the presence of the slightest trace of oxygen, and when such oxygen was present the molybdenum burned violently.

When the apparatus was apparently gas-tight, the current was turned on and a temperature of 1800° C. gradually attained and maintained for five minutes. A quantity of steam escaped from the apparatus, but all connections held, and the apparatus was free from leaks.

2.7091 grammes of Bessemer steel (0.1 per cent. carbon) was placed in an alundum boat lined with RR alundum furnished by the Norton Company, of Worcester, Mass. The boat was inserted in the tube and the temperature raised to 1650° C. Gas was evolved so rapidly that it could not all be collected. A sample taken when the evolution of gas had almost ceased proved to contain 95 per cent. nitrogen, 4.5 per cent. oxygen, and a trace of carbon monoxide. This proves that the nitrogen is held more firmly than the other gases, and is evolved finally only at very high temperatures.

Another determination was made operating on the same Bessemer steel (0.1 per cent. carbon). A sample of gas was collected when the temperature reached 1000° C.; another at 1250° C.; another at 1500° C., and the final sample taken at about 1675° C. The total amount of gas evolved from 7.162 grammes of steel was 201.2 c.c., equivalent to 28.1 c.c. per gramme, or 220 c.c. per c.c. of metal. The results of the analyses of these four samples of gas are as follows:

Analyses of Samples of Gas Taken.

Gas	At 1000° C.	At 1250° C.	At 1500° C.	At 1675° C.
Illuminants	.00	.00	.00	.00
Carbon dioxide	1.08	.62	.00	.00
Oxygen	2.4	3.07	4.28	6.25
Carbon monoxide	48.9	56.10	18.75	8.42
Hydrogen	21.16	15.08	4.20	1.10
Nitrogen	26.46	25.13	72.77	84.23
Total	100.00	100.00	100.00	100.00

GENERAL AND THEORETICAL.

It will be remembered that various authorities have arrived at the following conclusions regarding the effects of different gases in ferrous alloys:

The presence of occluded hydrogen apparently adds brittleness to a ferrous alloy, decreases its strength, and increases the hysteresis. The elasticity of such a specimen can be restored by removing the hydrogen.

The presence of occluded nitrogen increases the brittleness of a ferrous alloy, markedly affects its temper, and decreases its ductility. The strength is not markedly affected, but the hysteresis effect is increased. So far as the effect of occluded carbon monoxide is concerned, the experimental results are at variance, but it is apparent that the presence of carbon monoxide does not markedly change the strength, brittleness, or hysteresis of a specimen. J. E. Johnson, Jr., claims that the presence of oxygen in an iron is always attended with marked increase in strength of the specimen.

Our work has not progressed far enough to confirm all of these conclusions, but so far we have discovered nothing which would lead us to dispute these statements.

While it is true that gases exist in ordinary blowholes in the gaseous condition, it does not appear probable that ordinary occluded gases are present in metals in the gaseous state. If one considers the enormous pressures which these gases would exert, it appears that the alloy would not be strong enough to resist fracture. How then are these gases held? It might be possible that certain iron carbonyls, $Fe_x(CO)_y$, are present, but the iron carbonyls, which have been known and described, are all gaseous at the temperature of the solidification of iron. Of course, other carbonyls might be present. It is well known that iron carbides, iron nitrides, and iron hydrides exist. It is also true that iron oxides are present in most ferrous alloys. One can readily imagine a chemical reaction between iron oxide or iron carbonyl and a carbide of iron which would result in the formation of carbon monoxide or carbon dioxide. It is well known that hydrides of iron, on decomposition, yield metallic iron and hydrogen. It is also known that carbon dioxide and carbon monoxide are dissociated to an extent at high temperatures and yield carbon and oxygen; or, in the case of carbon dioxide, oxygen and carbon monoxide might result.

Mr. J. E. Johnson, Jr., has recently called attention to the fact that the presence of oxygen in charcoal was responsible for the superior qualities of charcoal iron, and states that he obtained oxygen from these high-grade irons. Whether or not the oxygen resulted from the decomposition of the oxides of iron or oxides of carbon has not yet been determined.

It has been observed that ferrous alloys made in electric furnaces, especially alloys particularly intended for tool steels, possess remarkable properties over the same alloys when produced in crucibles where the temperature is not as high as that attained in the electric furnace. It has also been determined that when these alloys are heated under the influence of a vacuum products possessing remarkable properties are secured. All this goes to show that the presence of certain gases exercises a deleterious effect on these alloys.

It is interesting to note that when iron is placed in an acidulated solution and made cathode it readily absorbs hydrogen. Curiously, this takes place below what is known as the decomposition voltage, at which point hydrogen and oxygen would be set free. If one connect a voltmeter and an ammeter in the circuit and apply a pressure below the decomposition voltage of the solution, one will notice that the ammeter indicates a flow of current and yet no gas is evolved. It is apparent that energy is being used up, and it is difficult to explain what becomes of this energy. Since it has been shown that hydrogen is absorbed by the iron, under these conditions, it is apparent that the energy requirement has been accounted for. Under these conditions the iron changes in molecular structure, as can be shown by micro-photographs.

This work is being continued, and consideration is being given to the physical changes incident to the removal of occluded gases from ferrous alloys. Tests on the samples, before and after treatment, involving (*a*) strength, (*b*) electrical properties, and (*c*) micro-structure, are in progress.

CONCLUSIONS.

1. We have constructed a gas-tight vacuum furnace, capable of continuous service at temperatures of approximately 1900° C.

2. By means of this apparatus, all the gases occluded in ferrous alloys may be removed and collected.

3. It appears that the gases are evolved in the following order: hydrogen is most readily set free, carbon monoxide comes next, and nitrogen seems to be held most tenaciously.

4. Whether oxygen is the result of the decomposition of various oxides of iron or the dissociation of carbon monoxide or carbon dioxide has not been determined.

5. We have shown that ferrous alloys may occlude relatively large volumes of gases—in some cases equal to about 200 times the volume of the metal.

6. We suggest that in addition to the ordinary functions of metals like aluminum, tungsten, chromium, manganese, titanium, silicon, etc., when placed in ferrous alloys these elements may act as a catalytic agent and either prevent the occlusion of large quantities of gases or aid in the elimination of such gases at lower temperatures than would ordinarily take place.

7. We have shown that the removal of gases from ferrous alloys markedly changes the micro-structure and increases the density of the alloy.

A NEW THEORY OF PLATE SPRINGS.*

BY

DAVID LANDAU and PERCY H. PARR.

PAPER I.

PROBABLY the first paper of historical importance in connection with the study of the strength of materials, which influenced the work of the elasticians of the seventeenth and eighteenth centuries, was that published by the famous Italian astronomer and physicist, Galileo Galilei, in 1638.

Galileo's paper was the forerunner of several others which were published, dealing with the strength and rupture of beams; it was Galileo who found that a "solid of equal resistance" must have a parabola for its generating curve.

English investigators speculated much upon the nature of bodies which were elastic, frequently quoting the Scriptures as authority for their deductions and reasonings. A curious example of these "speculations" into the cause of elasticity may be found in a paper by Sir William Petty on "The Discourse made before the Royal Society concerning the use of Duplicate Proportions; together with a New Hypothesis of Springing or Elastic Bodies" (London, 1674). The author describes a complicated system of atoms, which he endows with polar properties, and even sexual characteristics, in order to explain his theory.

Modern conceptions of elasticity no doubt began with Robert Hooke. In a work published in London in 1678 he informs us that eighteen years previously he had first formed his theory of springs. He purposely refrained from publishing his theory, as he was anxious to obtain a patent for a particular application of it. His Anagram, which concealed his theory, is too well known for repetition here; it need only be remarked that the clarity and generality of his statements lead us to say that Hooke is well deserving of the place he occupies in the history of elasticians of the first rank.

Chronologically, the next elastician of note was Mariotte; he was the first to recognize that in a beam subject to flexure one-half of the fibres are compressed, while the other half are extended. The term "fibre stress" must have had its origin about this time. Mariotte's work was published in Paris during 1686, and shortly thereafter G. W. Leibnitz stated that the stresses in the fibres are proportional to their extensions, thus applying Hooke's Law to single fibres.

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* Communicated by the Authors.

Varignon, whose work was published in Paris during 1702, and Parent (Paris, 1710) studied the form of solids of uniform resistance; James Bernouilli's work must be mentioned in passing.

Sir Isaac Newton's work in the cause of elastic studies is, so far as concerns us, of only passing interest; his brilliant efforts in the domain of mathematics, on the other hand, influenced every field of scientific investigation, and ours none the less. The greatest investigator of the Newtonian period, and probably Newton's equal, was the famous mathematician Euler. Lagrange, in 1771, published a paper of some interest dealing with springs.

A paper by James Jurin, "On the Action of Springs," in the *Philosophical Transactions for 1744,* deals with the application of Hooke's Law to a special case.

Coulomb's published work in 1784 on "Torsion Springs" referred to metallic wires, and his first paper, published in 1777, dealing with the torsion effects on hairs and silk fibres, while not immediately related to our present paper, had a general stimulating effect on investigations of the general theory of elasticity.

Thomas Young, the English physicist, gave, in 1807, his first exposition of what we now call the "modulus of elasticity," or "*E*." Young was not a mathematician, and his statements often lacked the clarity of exposition and generality which we get from mathematicians.

The modern theory of elasticity may be said to begin with Navier (1785–1836), who, in 1820, analyzed the flexure of rods and solved the problems relating to the reaction of flexible bodies for which the elementary statics afford no solution.

Poisson began those portions of his elastic researches which concern us in 1814; and it has been said of him that there was hardly a problem in the domain of the elastic theory which he did not in some way or another investigate; his nearest equal was Cauchy.

Mechanical engineering began to demand much from elasticians about 1840, and we find thus, as a result, the work of Poncelet on the "Theory of Resilience" which answered one of the demands. Lame and Clapeyron, studying the strength of iron used in bridges, founded, as a result of their practical studies, a most beautiful analysis in the field of elastic theory; their work greatly influenced all the later investigators. During the period 1840–50 appeared the works of Seebeck, Morin, Masson, Smith, and Newman, all of which are of sufficient importance to be mentioned here.

The greatest investigator, from our point of view, who combined practical knowledge with analytic ability of the highest order, and applied both to the study of the leaf spring, was, without doubt, E. Philips. Even at this late day, however, little is known of his work—even in his own country—France. An engineer by profession, yet an analyst of the most brilliant type, he alone attacked the problem of the plate spring in a truly scientific manner, and solved some of the most important problems requiring mathematical investigation. His researches were published in 1852, and almost every work on applied mechanics published since, which deals with the plate spring, has been based, to a greater or less extent, on his researches.

His paper, entitled "Memoire sur les Ressorts en Acier Employés dans le Material des Chemins de Fer," appeared in the *Annales des Mines,* Tome I, 1852, pp. 195–336.

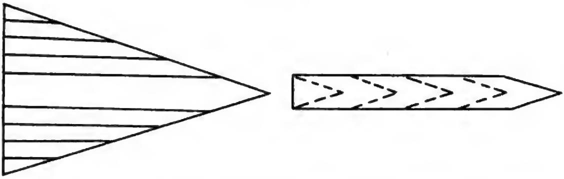
The Academy of France appointed a committee, consisting of MM. Poncelet, Seguier, and Combes, to investigate Philips's work; they reported concerning this work as follows: "*Le Travail de M. Philips sera fort utile aux ingénieurs et aux constructeurs, qu'y trouveront des régles rationelles et d'un application facile pour les établissements des ressorts capables des satisfaire, aux la moindre depénse de matière, à des conditions données de flexibilities et de résistance.*"

While there is no question as to the excellency of the work of Philips and its marvellous analysis of such a difficult problem, yet we do not quite agree with the committee's report. That the essence of the work of M. Philips may be "easily applied" to practical problems is a statement somewhat overdrawn; we confess, after a very careful and serious study of his memoir, that the applications of his equations are, in nearly all cases, most difficult, and, with the exception of a particular case, his expressions are outside of the range of practical utility. This does not vitiate, however, the scientific importance of this work. Philips published other papers, but the one mentioned is, for the present, the most important.

In 1880 a graphic application of Philips's work was made by Lèvy Lambert: the graphs given cover only special cases.

In 1865, A. Ritter published his "Lehrbuch der Technischen Mechanik," the third edition of which appeared in 1874. This contained, probably, the first text-book treatment of the plate spring. We mention this work as being a sample of the text-book treatment of the subject of the leaf spring which is often given at the present time. Ritter himself seems to have taken out only one special case of Philips's. Ritter applies the Bernouilli-Eulerian theory of beams to a cantilever having a constant thickness in the vertical plane of flexure, and finds that in a horizontal plane the beam must have the form of an isosceles triangle. He therefore builds a leaf spring formed from a series of leaves obtained by cutting the triangular cantilever, by placing the several plates as indicated by Fig. A. He pointed out the fact that each lamina, at the pointed end, presses on each succeeding lamina with a force P, equal to the load P. The result, naturally, is that each lamina, except the shortest, acts as a cantilever, with a load P at its apex and with a reactive supporting load P at the end of the next shorter lamina. The solution of this problem is then, of course, quite simple. No proof is offered of this exposition, and we suppose that he assumed Philips's work would answer the case in the affirmative. Ritter added nothing new to the subject, although his work has been copied widely, as he had probably copied Philips's.

FIG. A.



Ritter's work is of limited value, though correct, as we shall show later on, in so far as it deals with a special case; its limits have not been pointed out by any writer since his time, with possibly the one exception—Henderson.[1] Henderson, however, only added to Ritter's work by introducing "constants" for "full length" plates: he did not question the accuracy of Ritter's work, nor did he state the limitations of his own applications. A better attempt was made by E. F. Morrison,[2] although Marchesseau indicated a knowledge of this same idea in 1909.

Reuleaux, who in 1857 published his "Constructeur," merely expounded a particular case of Philips's; indeed, Reuleaux has too often been credited with originating equations which were the work of Philips.

As late as 1877, Philips's countrymen gave short abstracts of his work for the engineering fraternity, and among the best of these is that of Albert de Fierlant, who seems to have well understood his master. The last work of de Fierlant, published in 1889, is an excellent short exposition of Philips's special case.

No particular work of great importance seems to have been published since 1850, if we except the recent one by Paul Brennier, which treats of some new phases of the problem, and indicates briefly the inadequacy of Philips's treatment of the general subject. The work of Brennier is very interesting and deserves the careful study of the specialist.

Briefly, the foregoing remarks cover the history of the theory of leaf springs up to the present time. And for the reader who is interested in a critical study of the history of the theory of elasticity, we recommend the careful perusal of Todhunter and Pearson's "History of the Theory of Elasticity." Having outlined the work of the previous investigators, we make no apology for now introducing our own researches.

The study of the particular problem with which the present paper is concerned was commenced by us nearly sixteen years ago; the research was carried on intermittently, and some of the fundamental relations to be treated in the next instalment were discovered but a few years ago.

During the last ten years we have searched, often with the assistance of many others, through the technical literature of the Old and the New Worlds, in order to discover what researches, if any, had previously been made by the earlier mathematicians and engineers which resembled our own. So far we have found but a single paper of importance, that of the famous French mathematical engineer, M. Philips, who, as mentioned in our historical *résumé,* made a study of the leaf spring [3] initiated on lines akin to our own; his theses, however, gave the mathematical relations in such complex form as to be of but slight use to the engineer and designer. The theory of Philips was not developed to an extent and direction which is in any way comparable with our own researches.

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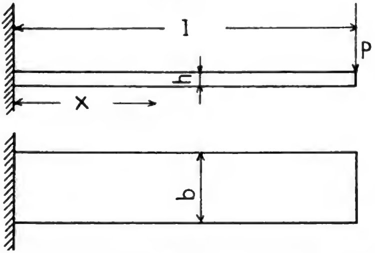
[1] G. R. Henderson, *Trans. A. S. M. E.*, vol. xvi.

[2] *Machinery Eng.*, ed. January, 1910.

"The prevailing and generally accepted hypothesis on which is based the so-called 'scientific' design of plate springs is only a slight modification of the most elementary concepts and analyses of the early teachers of theoretical mechanics." We shall show that their hypotheses are totally inadequate to explain the complete phenomena of leaf-spring action, and that, without the complete analysis, which our theory enables us to make, no true scientific leaf-spring design is possible.

FIG. 1.



The application of the results of our investigation to practice has resulted in springs having an endurance, or life, far greater than usually obtained, and our springs have been a revelation even to those skilled in the art of spring making; in fact, on more than one occasion we have been charged with obtaining the enormous endurance shown by springs designed in accordance with our theory by some mysterious heat applications during the thermal treatment.

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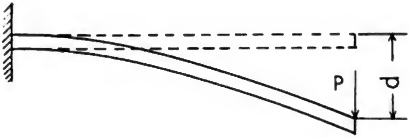
[3] *Annales des Mines,* 1852, 1, 195.

In order to lead to a complete understanding of our theory of the leaf spring it seems best to explain first, in as elementary a manner as possible, the prevailing commonly accepted theory of to-day. Our exposition may be somewhat different from some of those given in the text-books on applied mechanics, but the essentials and the results are the same.

Consider a single leaf as shown in Fig. 1, having a length l, a constant thickness h, and a constant width b; fixed at one end and subjected to a load P at the other end. Under these conditions the plate will deflect a distance, say d, as shown in Fig. 2. Of course, we assume in this exposition that any leaf spring may be considered as a beam encastre at one end and loaded at the other, as is the case with a cantilever spring; other springs (such as semi-elliptic springs) may, if desired, be considered as beams supported at the ends and loaded at the centre; the final result, however, is exactly the same as if they are considered as two cantilevers joined at the points of encastrèment. It suffices, therefore, to consider the case of the cantilever.

FIG. 2.

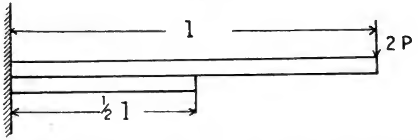


Suppose, now, that we arrange some suitable mechanism which shall vibrate this simple, one-leaf spring through the distance d such a number of times as shall cause it to break. Clearly, the fracture will occur at the point of fixation, for the bending moment, which is evidently $P\ (l-x)$, there attains its maximum value Pl; and, as the section of the leaf is uniform, the stress is a maximum at the same section as the bending moment.

The number of vibrations required to break the one-leaf spring having been determined, we may now propose the problem of constructing a spring to carry twice the load, or $2P$, and to deflect the same distance d, and also to withstand the same number of vibrations as before. How should we, in accordance with the present-day theory, make a spring to fulfil these requirements, it being understood that the length l must not be altered? The answer of the present-day theory is given by Fig. 3.

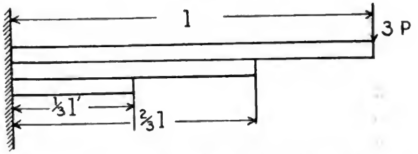
A second leaf, called the short leaf, and in this case having a length $\frac{1}{2}\delta_2$, would be placed under the original leaf. The prevailing theory advises that the resulting spring of Fig. 3 will support, with equal safety and equal deflection, a load of double that of our original one-leaf spring, or $2P$ if the load for the single leaf is P.

FIG. 3.



Again, the theory in common use to-day indicates that the spring to carry $3P$ must be made as shown in Fig. 4, where it will be seen that the second leaf has a length of $\frac{2}{3}l$ and the short leaf a length of $\frac{1}{3}l$. In general, this theory assumes that "the number of leaves is directly proportional to the load." It should be noted that the "steps" or "overhangs" are all equal.

FIG. 4



For the present we are considering only springs composed of leaves of the same cross-section; later on we shall discuss the effect of varying the sections, or "grading" the springs.

Now, suppose that we consider a spring such as that shown in Fig. 4, and ask if the stresses are the same in all of the leaves, and if the maximum stress in each leaf is the same as that in the simple leaf of Fig. 1. The answer given by those who expound the ordinary theory is about as follows:

They say (in the case of Fig. 3) that, since the load is doubled, so is the maximum bending moment, the length being the same, and as the section modulus is also doubled, the stress is $\frac{2Pl}{2Z} = \frac{Pl}{Z}$ the same as before. Likewise at the point $\frac{l}{2}$ the bending moment is $\frac{2Pl}{2} = Pl$, so the stress there is the same as at the point of fixation. An exactly similar line of reasoning is applied to Fig. 4, and so on for any number of plates.

If we accept these statements as true—and the deductions are correctly made from the original assumption of the theory—then we must expect, *a priori,* that in any such spring each and every plate is liable to the same mathematical probability of concomitant failure.

How far is this concept verified by experiment? This is the crucial test to which all mechanical theories must submit; and any failure of a theory to explain the test results in a satisfactory manner is a proof of its inadequacy. The experimental verification of the theories of leaf springs was made possible by the endurance testing machine.

Imagine that we have constructed springs of, say, 2, 3, 4, ... , etc., plates, the master leaf[4] being the same length in each spring, and all the leaves having the same cross-section; also that we put these springs into a vibratory testing machine, making each deflect the same distance *d*. What will happen? Since we have conducted exactly such a series of tests, we are able to give a definite reply to this question.

We tested 33 springs containing 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, and 13 plates. All these springs were carefully constructed so as to reduce accidental errors to a minimum. The results of these tests were most astonishing; in each case (except two only) only one leaf in each spring broke and the broken leaf was always the shortest one! Why? In accordance with the usual theory, all the leaves composing the spring—or at least several of them—should have broken at one and the same time, and the liability of each leaf to fracture should be exactly the same, so that with our considerable number of tests we should have had broken leaves in many positions in the springs. Why this enormous deviation from the results predicted by the theory? We must add another observation of great importance: in no two cases were the number of vibrations required to break the short leaf the same; on the contrary, *the number of vibrations required to break the short leaf decreased as the number of leaves in the spring increased!*

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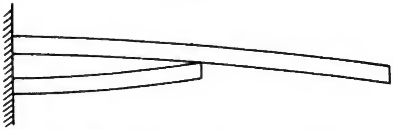
[4] The longest leaf of a spring, usually having eyes rolled or forged at the ends, is technically called the "master leaf," "main leaf," or "back."

Here we have the results of careful experimental work which seemed to indicate the reverse of the theoretical prediction—a theory which has not been questioned since it was first proposed, probably in 1852—66 years ago! Various explanations were offered to account for the results, and among them the one which appeared to be the most logical and reasonable follows.

Consider, for simplicity, a two-leaf spring such as that shown in Fig. 3, and suppose it to be so constructed that when it is not loaded, or, as we prefer to term it, "free," it is perfectly flat (if arched when free, it does not materially change the reasoning). Now, it is well known to engineers that in the making of a spring each leaf is given a different radius of curvature, as shown roughly by Fig. 5. When the leaves are clamped together by the centre bolt, note that the leaves are deflected in opposite directions; the master leaf is deflected upward at the ends, or in the opposite direction to the deflection caused by the external load, while the short leaf is deflected downward, or in the same direction as the deflection caused by the external load. As a consequence, it follows that the short leaf of a spring, no matter what the number of leaves, is thereby *already loaded positively*. Similarly, the upper leaf is *unloaded* or loaded negatively. These initial loading and unloading effects produced by the method of manufacture are present in all commercial leaf springs, though in different degrees.

Fig. 5.



This method of building leaf springs with initial deflections of the separate lamina, technically called "nip," helps the old theory to explain the breaking of the short leaf first. For it is argued, and reasonably, that, since the short leaf is already positively stressed by the nipping load, this stress must be added to that produced by the external load, with the result that the short leaf has the greatest stress in it, and will therefore be the first to break. This appears to be a fair explanation of one of the facts brought to view by the destruction tests; but when put to a further test, however, the explanation fails utterly.

We built approximately the same number and the same kind of springs as those mentioned previously, but having one important difference: all of these series of springs were built with leaves that were practically "nipless"; in other words, the leaves were so curved that when laid one against the other, without any pressure being applied, the adjacent leaves touched practically everywhere along their entire length, or they were (in shop parlance) "dead." There were, therefore, no initial flexural stresses in these springs.

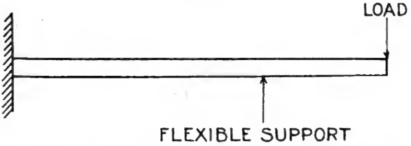
These nipless series of springs were then placed in the endurance testing machine, with the expectation (by those not acquainted with our theories) that several leaves would break at once, and that the fractures would occur in various positions in the springs. What we did obtain was a surprise! All the nipless springs broke the short leaf first, just the same as before!—although one very noticeable difference was found; namely, that the number of vibrations required to cause fracture was increased. This latter result might, of course, have been anticipated *a priori*, but that the short leaf should continue to break first, and with such repeated insistence, was a great surprise to those who were not acquainted with the new theories which the present paper expounds.

Many other experiments were made, but one only is of interest here. In a series of springs, all the leaves above the shortest were made of plain carbon spring steel; the shortest leaves alone were made of high-grade alloy-steels (silico-manganese and chrome-vanadium were used in alternate tests). The endurance results showed that, while the number of vibrations required to cause breakage was somewhat increased, the short leaf persistently continued to fail first.

These facts, constantly shown by the endurance testing machine, and so often confirmed from observation of leaf springs in practice, together with the fact that it has been found necessary in railway as well as in automobile practice to adopt a "constant" in the ordinary formula for the strength of leaf springs which allows for a very nominal working stress, all indicated the necessity for a new analysis, of quite a different character from that of the academic texts. It is this new analysis, the result of several years of investigation, and of continued experimental work and practical application, which we now publish for the first time.

The new theory has one important element in its favor—it explains exactly everything that has needed an explanation; analyzes fully and completely the minute details of the behavior of each leaf and the stress at every point in the leaves; predicts with certainty the endurance of each leaf comprised in a spring. It has explained, easily and consistently, each and every one of the numerous apparent inconsistencies shown by the many tests which have been made, and also the results found "on the road." It has enabled us to build springs having a far greater endurance than those designed on the basis of the old theory, and experience indicates that we can expect to obtain even better results in the near future.

FIG. 6.



THE NEW THEORY OF LEAF SPRINGS.

If a series of laminæ having the form of a cantilever, and having equal widths and equal or different thicknesses, be assembled so as to form a leaf spring, and such spring be loaded in the usual manner, it will be found that each leaf touches the one above it only at the point of encastrèment and its extremity. This may readily be shown theoretically, and is obvious in practice, as will be admitted by all who have examined the wear on spring leaves which have been in use for some time—it being understood that leaves with ordinary non-tapered ends are here being considered, and not the special cases to be considered later of the tapered leaf spring. The relations given in this exposition refer primarily to "square point" leaves; we have made elaborate investigations of the effects of tapered points, but these are to be treated in another paper; the present paper is intended to deal mainly with the fundamental relations.

Any leaf of a spring except the short plate may be considered as a beam, encastrè at one end, loaded at the other, and having a flexible support somewhere between the point of encastrèment and that of application of the load, and this is the fundamental assumption on which our new theory of leaf springs is based. This fundamental principle is illustrated by Fig. 6; its adoption leads to many special and interesting relations, a few of which we will proceed to develop.

Let l = the half length of the short leaf for a semi-elliptic spring, or the length for a cantilever spring; l_2 that for the second leaf, etc., so that l_n is the length for the nth leaf;
M = the bending moment at any section;
I_n = the moment of inertia of the section of the nth leaf;
E = the modulus of direct elasticity of the material;
W_n = the reaction, or pressure, between the end of the nth leaf and the $n+1$th leaf;
x = the distance of any section under consideration from the point of encastrèment;
y = the deflection at any point; and
δ_n = the deflection at the end of the nth leaf, where W_n acts.

The fundamental relation between the curvature (in ordinary cases) and the bending moment is well known to be:

$$EI\frac{d^2y}{dx^2} = M \qquad (1)$$

Now, referring to Fig. 7, it will be seen that for the $n+l$th plate, we must have; for

$$o \leqslant x \leqslant l_n$$

$$M = EI_{n+1}\frac{d^2y}{dx^2} = W_{n+1}(l_{n+1} - x) - W_n(l_n - x) \qquad (2)$$

and for

$$l_n \leqslant x \leqslant l_{n+1}$$

$$M = EI_{n+1}\frac{d^2y}{d^2x} = W_{n+1}\ (l_{n+1} - x) \qquad (2a)$$

Integrating, and noting that $EI_{n+1}\frac{dy}{dx}$ from (2) must be equal to $EI_{n+1}\frac{dy}{dx}$ from (2a) when x has the value l_n, we obtain: for

$$o \leqslant x \leqslant l_n$$

$$EI_{n+1}\frac{dy}{dx} = W_{n+1}\left(l_{n+1} - \frac{x^2}{2}\right) W -_n \left(l_n x - \frac{x^2}{2}\right) \ldots\ldots (3)$$

and for

$$l_n \leqslant x \leqslant l_{n+1}$$

$$EI_{n+1}\frac{dy}{dx} = W_{n+1}\left(l_{n+1} - \frac{x^2}{2}\right) - W_n\frac{l_n^2}{2} \ldots\ldots (3)$$

Integrating again, and noting the equality of $EI_{n+1}\,y$ from (3) and (3a) for $x = l_n$, we obtain for

$$o \leqslant x \leqslant ln$$

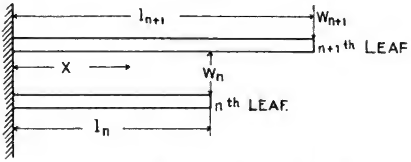
$$EI_{n+1}y = W_{n+1}\left(\frac{l_{n+1}x^2}{2} - \frac{x^3}{6}\right) - W_n\left(\frac{l_n x^2}{2} - \frac{x^3}{6}\right) \ldots\ldots (4)$$

and for

$$l_n = x = l_{n+1}$$

$$EI_{n+1}y = W_{n+1}\left(\frac{l_{n+1}x^2}{2} - \frac{x^3}{6}\right) - W_n\left(\frac{l^2_n x}{2} - \frac{l^3_n}{6}\right) \ldots\ldots (4a)$$

FIG. 7.



Putting $x = l_n$ in (4) and $x = l_{n+1}$ in (4a) we obtain:

$$EI_{n+1}\delta_n = W_{n+1}\left(\frac{l_{n+1}l_n^2}{2} - \frac{l_n^3}{6}\right) - W_n\frac{l_n^3}{3} \ldots\ldots (5)$$

$$_{n+1}\delta_{n+1} = W_{n+1}\,\frac{l^3_{n+1}}{3} - W_n\left(\frac{l^2_n l_{n+1}}{2} - \frac{l^3_n}{6}\right) \ldots\ldots (5a)$$

Now putting n for $n + l$ in (5a) there results:

$$EI_n\delta_n = W_n\frac{l^3_n}{3} - W_{n-1}\left(\frac{l^2_{n-1}\,l_n}{2} - \frac{l^3_{n-1}}{6}\right) \ldots\ldots (6)$$

And equating the values of δ_n as given by (5) and (6) we obtain (we assume the material of all the leaves to be the same, so that the E's are equal):

$$6\,E\delta_n = \frac{W_{n+1}\,(3l^2_n l_{n+1} - l^3_n) - 2W_n l_n^3}{I_{n+1}} = \frac{2W_n l_n^3 - W_{n-1}\,(3l_{n-1}^2 l_n - l^3_{n-1})}{I_n} \ldots (7)$$

If the material of the leaves be different, then equation (7) becomes:

$$6\delta_n = \frac{W_{n+1}(3l_n^2 l_{n+1} - l_n^3) - 2W_n l_n^3}{E_{n+1} I_{n+1}} = \frac{2W_n l_n^3 - W_{n-1}(3l_{n-1}^2 l_n - l_{n-1}^3)}{E_n I_n} \ldots\ldots (7a)$$

Equation (7a) is only of academic interest, for clearly the material of all the leaves in any spring is always the same; still we wish to indicate the generalization of the theory. The reader may find interest in working out a composite spring in which the leaves are composed of materials having various values of E.

Equation (7) is the most important and fundamental relation between the lengths of the leaves and their corresponding reactions or tip pressures, W. For any particular spring of given dimensions, the reactions may readily be determined in progressive order, starting with the bottom or short leaf.

For the short leaf we have $n = 1$, and $l_0 = 0$, so that the relation between the short leaf and the second one is:

$$\frac{W_2(3l_1^2 l_2 - l_1^3) - 2W_1 l_1^3}{I_2} = \frac{2W_1 l_1^3}{I_1}$$

and since the l's are usually given, the W's are determined from this relation. Knowing the loads and the lengths, as well as the cross-sections, the stresses are then readily found.

Equation (7) explains the many difficulties and inconsistencies found when endeavoring to force the old theory into agreement with practice; it shows at once that the strength of a spring is not nearly in direct proportion to the number of plates. It interprets, without any modification, the reason for the failure of the short leaf of any ungraded spring, and of nearly all the graded ones; it shows the reason why the endurance at a given deflection decreases with the increase in the number of leaves. and it fully explains many apparent inconsistencies which we have met with on the endurance testing machine, and the results of practice.

Having now shown the derivation of one of our fundamental formulæ, we propose to show its application to the study of particular cases. Not the least of its usefulness will be found in its application to the study of the exact character of the deflection experienced by each leaf of a spring. We shall show further that equation (7) explains fully all the difficulties indicated by the endurance tests mentioned previously, and also many others for which the old theory is unable to offer any rational explanation.

We may mention here that the fundamental reason for failure of the old theory is that it ignores the clamping of the leaves at the centre of a semi-elliptic spring, or at the end of a cantilever spring. The old theory assumes each plate can move vertically and independently at the point of encastrèment, and it is quite correct if such a condition holds; this condition never does hold in practice, and the effect of the clamping is sufficient to vitiate the old theory to such an extent as to render it useless from both the theoretical and practical points of view.

We will now apply our established equations to see what they may reveal; we will also test them to discover if they are capable of explaining the facts revealed by the endurance tests mentioned in the earlier portion of this paper.

As the simplest elementary case let us apply the fundamental equation (7) to a two-leaf spring. We will take the overhangs equal, so as to get an exact comparison with the results of the old theory as outlined above.

If the plates are of the same cross-section, the moments of inertia are equal, then the fundamental equation becomes:

$$W_{n+1}(3l^2_n l_{n+1} - l^3_n) - 2W_n l_n^3 = 2W_n l_n^3 - W_{n-1}(2l_n{}^2{}_{-1} l_n - l_n{}^3{}_{-1})$$

or for the present case, where $n = 1$ and $l_2 = 2l_1$, we have:

$$W_2(3l^2_1 l_2 - l_1^3) - 2W_1 l_1^3 = 2W_1 l_1^3 - W_0(3l^2_0 l_1 - l_0^3)$$

and as $l_0 = 0$ (has no existence), the last term vanishes, and l_1 cancels, leaving:

$$5W_2 - 2W_1 = 2W_1,$$

or

$$W_2 = \tfrac{4}{5} W_1$$

Here we see that the new theory indicates the reactions are not at all equal. To put it into words, our theory shows that for a unit load W to act on the point of the short leaf, the load applied to, or the pressure required on the end of the next longer leaf, is only 4/5 of the unit load W_1; or, for unit load placed on the end of the second leaf (in the present case the master leaf, there is produced a reaction or pressure on the end of the short leaf equal to 5/4 times the unit load. This is a very different result from that given by the old theory, and shows that the actual stress in the short leaf is 25 per cent. more than is accorded to it by the old theory.

The maximum bending moment on the short leaf is W_1l_1; that on the plate next above it is

$$W_2(l_2-l_1)=W_2(2l_1-l_1)=W_2l_1=\tfrac{4}{5}W_1l_1.$$

This calculation shows conclusively that the stress in the master leaf of a two-leaf spring, at its maximum value, can be only four-fifths of that in the short leaf. We see thus that the actual stress in the short leaf, according to our theory, is considerably the greater, which therefore accounts exactly for the results our experiments persisted in showing and which is so frequently observed in practice; namely, that the short leaf fails first.

FIG. 8.

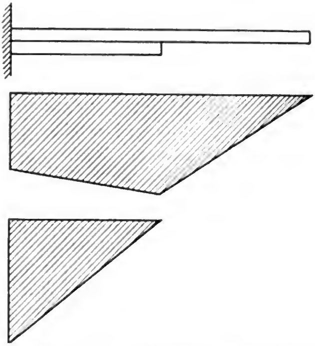


Fig. 8 shows clearly, in graphic form, the stress at every section of both plates; it will be noticed that the stress in the short lamina increases from zero at the end to a maximum at the point of fixation, while at the same time the stress in the master leaf increases from zero at the end to a maximum, which maximum occurs directly over the end of the short leaf, and then gradually *decreases* towards the point of fixation. The maximum stress in the master leaf is thus only four-fifths of that in the short leaf, and the stress in the master leaf at the point of fixture is only three-fifths of that in the short leaf at the same place. It should be noticed, too, that the distribution of the stress is entirely different for the two leaves—a condition not even suspected heretofore.

Our next point is of still greater interest: it deals with the practical issue of the permissible loads which any spring may safely carry according to this new theory.

Since the short leaf of the two-leaf spring just considered is but one-half of the length of a single-leaf spring, the actual load W_1 which may be placed upon it is evidently equal to $2W_1$ (since for the same stress the load varies inversely as the length); hence, to produce double the pressure or reaction on the end of the short leaf we must place, on the end of the main leaf, $4/5$ of the double, or $8/5 = 1.6$ times the load that we can put on a single-leaf spring! Hence the conclusion, from the application of this new theory to a two-leaf spring, is that such a two-leaf spring having plates of the same cross-section, and equal steps, is only capable of carrying 1.6 times the load of a one-leaf spring. The old theory, then, which states that a two-leaf spring is double the strength of a single leaf spring is therefore seen to be quite incorrect. Hence it follows, from what we have shown, we are correct in saying that *a two-leaf spring has 1.6 times the strength of a single-leaf spring*, and it is in this sense that we shall continue to use the word "strength" as applied to a spring; namely, the ratio of its supporting capacity (for a given maximum fibre stress in any one leaf) to that of a single leaf with the same maximum fibre stress.

A further application of our theory, quite similar to that just given, shows that a three-leaf spring has not a strength of 3, but only of 2.207; a four-leaf spring has a strength of 2.817, and a ten-leaf spring only 6.503. A twenty-leaf spring has a strength of but 12.689, instead of 20, as given by the old theory, the reduction of strength being therefore almost 40 per cent. These figures show very definitely the cause of failure from overloading springs designed on the assumption that the strength of such leaf springs varies in direct proportion with the number of leaves; it also shows why, when using the old formulæ, it has been found necessary in practice to adopt a "coefficient" allowing for an abnormally low apparent stress as mentioned above; the fact being, of course, that the actual stress is very much higher—a condition our theory shows rationally.

In practice it may be observed that for springs having a considerable number of plates there is, in addition to the master leaf, one or even several leaves having the same length as the master leaf; these leaves are called "full-length leaves." Our fundamental equation (7) deals readily with these cases, for any number of full-length leaves are exactly equivalent to a single leaf with a moment of inertia equal to the sum of the moments of such full-length leaves, and the fundamental equation allows for any relation between the moments of inertia of the various leaves.

To avoid tedious calculation of the reactions in each case, we have calculated the values of the reactions, as well as the strengths, for springs having up to as many as 20 leaves with one full-length leaf, and up to 25 leaves with 6 full-length leaves; these calculations are summarized in Tables I and II. In both of

TABLE I.

Reactions.

EQUAL SPACING.

K	$p=1$	$p=2$	$p=3$	$p=4$	$p=5$	$p=6$
1	1.0000	2.0000	3.0000	4.0000	5.0000	6.0000
2	.8000	1.2000	1.6000	2.0000	2.4000	2.8000
3	.7357	1.0144	1.2931	1.5718	1.8505	2.1292
4	.7044	.9184	1.1324	1.3464	1.5604	1.7744
5	.6860	.8598	1.0336	1.2074	1.3812	1.5550
6	.6740	.8203	.9666	1.1129	1.2592	1.4055
7	.6655	.7918	.9181	1.0044	1.1707	1.2970
8	.6591	.7702	.8813	.9924	1.1035	1.2146
9	.6542	.7534	.8526	.9519	1.0511	1.1503
10	.6503	.7399	.8295	.9191	1.0087	1.0983
11	.6471	.7287	.8104	.8920	.9737	1.0553
12	.6445	.7195	.7945	.8695	.9445	1.0195
13	.6423	.7117	.7811	.8504	.9198	.9892
14	.6404	.7050	.7696	.8341	.8987	.9633
15	.6388	.6992	.7596	.8200	.8804	.9408
16	.6375	.6943	.7510	.8078	.8645	.9313
17	.6365	.6900	.7435	.7971	.8506	.9042
18	.6356	.6863	.7369	.7876	.8383	.8890
19	.6350	.6831	.7312	.7793	.8274	.8756
20	.6344	.6802	.7260	.7718	.8176	.8634

these tables p is the number of full-length leaves in the spring, including the master leaf, k is the number of steps in the spring, and n is the total number of leaves, so that $n = k + p - 1$. Knowing the reactions, which are given in Table I, the strengths given by Table II are easily determined.

TABLE II.

Strength of Springs.

EQUAL SPACING.

K	$p=1$	$p=2$	$p=3$	$p=4$	$p=5$	$p=6$
1	1.000	2.000	3.000	4.000	5.000	6.000
2	1.600	2.400	3.200	4.000	4.800	5.600
3	2.207	3.043	3.879	4.715	5.551	6.387
4	2.818	3.674	4.530	5.386	6.242	7.098
5	3.430	4.299	5.168	6.037	6.906	7.775
6	4.044	4.922	5.800	6.678	7.556	8.434
7	4.658	5.542	6.426	7.310	8.194	9.078
8	5.273	6.162	7.051	7.940	8.829	9.718
9	5.888	6.781	7.674	8.567	9.460	10.353
10	6.503	7.399	8.295	9.191	10.087	10.983
11	7.118	8.016	8.914	9.812	10.710	11.608
12	7.734	8.634	9.534	10.434	11.334	12.234
13	8.350	9.252	10.154	11.056	11.958	12.860
14	8.966	9.870	10.774	11.678	12.582	13.486
15	9.582	10.488	11.394	12.300	13.206	14.112
16	10.200	11.108	12.016	12.924	13.832	14.740
17	10.820	11.730	12.640	13.550	14.460	15.370
18	11.441	12.353	13.265	14.177	15.089	16.001
19	12.055	12.969	13.883	14.797	15.711	16.625
20	12.688	13.604	14.520	15.436	16.352	17.268

A study of Table II of the relative strengths of leaf springs will reveal a very interesting point which is brought to light by the present theory; namely, that to carry too many full-length leaves in a spring is a decided disadvantage. Thus a two-leaf spring is seen to have a strength of 1.6 and a three-leaf spring a strength of 2.207, while a three-leaf spring with $p = 2$ has a strength of 2.4, and with $p = 3$, or all the leaves full-length, a strength of 3, as might be expected *a priori*. A four-leaf spring with $p = 1$ has a strength of 2.818, and with $p = 2$ it has a strength of 3.043, which again agrees with expectation But now observe that a four-leaf spring with $p = 4$ has a strength of 4, while a five-leaf spring with $p = 4$ is no stronger; this seems strange. Then notice that a five-leaf spring with $p = 5$ has a strength of 5, while a six-leaf spring with $p = 5$ has a strength of only 4.8; the addition of a short leaf has thus actually weakened the spring. Of course, such designs are outside of working experience, but the point is of considerable interest, as it shows that where there are several plates of the same length the addition of a shorter plate may actually weaken the spring. This is a condition which the old theory would never have suspected. We see, therefore, that there are limits to the corrected empiric equations of Henderson or Morrison which they did not announce; the absence of the *rationelle* of the correct theory of leaf springs naturally accounts for their not stating the limits in their expositions.

DEFLECTION OF SPRINGS.

The deflection of a spring has long been a favorite in engineering discussions as a means of verifying the old academic theory of the leaf spring. The practical deflection results having often been found to be in fair agreement with the academic predictions, they have frequently been urged as a confirmation of the theory (we may here mention that our theory shows that in general the deflection errors of the old theory are much less than the stress errors). The many discrepancies which did occur were explained by a series of carefully phrased objections which apparently answered the purpose up to the present time. Thus we find that if the calculated deflection was smaller than that found on a test, it was easily explained as due to the friction of the leaves, or "modulus variation" of the steel, etc. As a matter of fact, carefully conducted tests showed that none of the factors mentioned could explain the large differences often found between the "theoretical" and the "practical" deflections. The failure of the old theory is due to its real and inherent deflects, and not to any imaginary variations of the material, etc. Thus, for example, the old theory supposed that the reactions are equal, which we have shown to be very far from the fact; it necessarily follows, therefore, that there must be analogous errors in the assumption for the deflection formulæ.

The old theory shows, for example, that the deflection of a two-leaf spring under a load of $2W$ is the same as that of a single-leaf spring under a load of W. Indeed, the old theory says that the deflection is inversely proportional to the number of leaves in the spring (supposing all to be of the same cross-section), or that it is inversely proportional to EI at the centre of the spring. The old theory does not consider the effect produced by changes in the length of the steps; it does not, in fact, consider the effect of the stepping at all. The mere mention of this fact is sufficient to show that the old theory is inadequate; a very serious error may easily be committed by ignoring the effect of the stepping on the deflection of a spring, as may be gathered from our fundamental equation (7), which shows that the deflection depends on the length of each and every plate.

For springs having all the leaves of the same cross-section, the deflection may be expressed by a simple formula as follows: The fundamental relation of equation (7) becomes:

$$\delta_n = \frac{2W_n l_n^3 - W_{n-1}(3l_n^2 l_{n-1} - l_{n-1}^3)}{6EI}$$

$$= \frac{W_n l_n^3}{EI}\left\{\frac{2 - \frac{W_{n-1}}{W_n}\left[3\left(\frac{l_{n-1}}{l_n}\right)^2 - \left(\frac{l_{n-1}}{l_n}\right)^3\right]}{6}\right\}$$

which is of the form

$$\delta_n = \frac{CW_n l_n^3}{EI} \quad \text{(8)}$$

where C represents the function in the brackets; we have calculated the values of C for many cases, and these are given in Table III. As an example, if l, E, and I are constant, the deflection will be directly proportional to CW, and we will take W to be unity for a single-leaf spring, so that $CW = 0.33333$. Then for a two-leaf spring W will be 1.6 from Table II, and C will be 0.20313 from Table III; so that $CW = 0.32401$, which is appreciably less than the 0.33333 for the single-leaf spring. For a ten-leaf spring we have $6.50 \times 0.04813 = 0.31299$, which is still less; the old theory says, however, that they would all be the same. At the same time, it will be noticed that the error of the deflection given by the old theory is much less than the error of the stress, as previously mentioned.

Now that we have established the fundamental relations,

TABLE III.
Deflection Coefficients.
EQUAL SPACING.

K	$p=1$	$p=2$	$p=3$	$p=4$	$p=5$	$p=6$
1	.3333	.1667	.1111	.0833	.0667	.0556
2	.2031	.1233	.0894	.0703	.0580	.0493
3	.1456	.0986	.0755	.0614	.0517	.0447
4	.1130	.0822	.0654	.0545	.0464	.0410
5	.0924	.0706	.0578	.0491	.0427	.0378
6	.0781	.0618	.0518	.0447	.0393	.0352
7	.0676	.0550	.0469	.0410	.0365	.0328
8	.0596	.0495	.0429	.0379	.0340	.0308
9	.0532	.0451	.0395	.0352	.0318	.0290
10	.0481	.0413	.0366	.0329	.0299	.0274
11	.0447	.0385	.0343	.0310	.0283	.0261
12	.0404	.0355	.0319	.0290	.0267	.0247
13	.0373	.0330	.0299	.0274	.0253	.0235
14	.0347	.0311	.0283	.0260	.0241	.0225
15	.0325	.0293	.0268	.0248	.0230	.0215
16	.0306	.0277	.0255	.0236	.0220	.0206
17	.0289	.0263	.0243	.0226	.0211	.0199
18	.0273	.0250	.0231	.0216	.0203	.0191
19	.0260	.0238	.0221	.0207	.0195	.0184
20	.0247	.0227	.0212	.0199	.0188	.0178

we propose to show other new relations of practical interest which our theory enables us to formulate.

We have seen that in the ordinary leaf spring with equal steps the reactions are not equal, and the stresses are not equal either. It may therefore occur to the reader that if it were possible to make the reactions equal we might also obtain equal stresses. The attempt would therefore be to question the effect produced by, say, for example, altering the steps, or changing the lengths of the leaves. To make the reactions equal in any spring is easily done by an application of the fundamental equation (7), which now becomes:

$$3l_n^2 l_{n+1} - l_n^3 - 2l_n^3 = 2l_n^3 - 3l_{n-1}^2 l_n + l_{n-1}^3$$

or

$$3l^2_n l_{n+1} = 5l_n^3 - l_{n-1}^2 (3l_n - l_{n-1})$$

for, as the W's are now supposed to be equal, they naturally cancel, and for the present we are considering only leaves of the same cross-section, so that the I's are also equal. For $n = 1$ this equation evidently becomes:

$$3l_1^2 l_2 = 5l_1^3 - l_0^2(3l_1 - l_0)$$

and the last term vanishes as before, since $l_0 = 0$, and on dividing by $l^3{}_1$, there results:

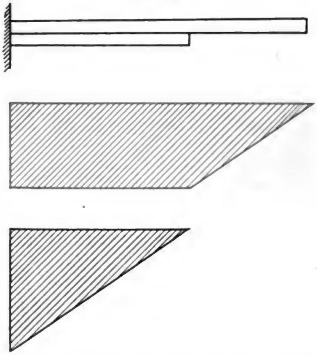
$$3l_2 = 5l_1$$

or

$$l_2 = \tfrac{5}{3}l_1$$

and this is the answer to the question proposed for the two-leaf spring. For further reference we may consider Fig. 9.

FIG. 9.



The maximum bending moment in the short leaf is Wl_1, and in the master leaf is $W(l_2 - l_1) = 2/3Wl_1$. Now, since l_1 is three-fifths of l_2, the maximum bending moment on the short leaf is three-fifths of what it would be with a single-leaf spring, and, reciprocally, the strength of a two-leaf spring made to these proportions is $5/3 = 1\tfrac{2}{3}$ times that of a single-leaf spring, or $66\tfrac{2}{3}$ per cent. more, when the reactions were made equal. This is greater than the strength of an equally stepped spring, because the bottom leaf is longer. Indeed, the longer the bottom leaf (after a certain minimum), the greater the strength of the spring.

We have calculated out Tables IV, V, and VI, which show respectively the length of each plate necessary to secure equal reactions, the relative strengths of the various springs, and the deflection coefficients C for use in equation (8).

TABLE IV.

Overhangs.

EQUAL REACTIONS.

Plate No.	Overhang	Sum of overhangs = length of top plate
1	1.0000	1.0000
2	.6667	1.6666
3	.6312	2.2979
4	.6153	2.9132
5	.6061	3.5193
6	.6001	4.1194
7	.5958	4.7152
8	.5926	5.3078
9	.5901	5.8979
10	.5882	6.4861
11	.5866	7.0727
12	.5852	7.6579
13	.5841	8.2420
14	.5831	8.8251
15	.5822	9.4073
16	.5814	9.9887
17	.5807	10.5694
18	.5802	11.1496
19	.5797	11.7293
20	.5792	12.3085

The general laws which the preceding study enables us to formulate with regard to non-tapered leaf springs are:

1. In any leaf spring having leaves of equal cross-sections, and with equal steps, the reactions or pressures between the leaves continually decrease from the short leaf toward the master leaf, as do likewise the stresses.

2. In any leaf spring having leaves of equal cross-sections, and in which the reactions or pressures between the leaves are equal, the steps or overhangs continually decrease from the short leaf toward the master leaf.

In Fig. 9 we show graphically the result of making the reactions equal, and its effect on the stress distribution. The stresses are greatly altered, and are made uniform in the longer leaf for a distance of three-fifths of its length. This graphic analysis shows also why we can carry a greater safe load on this spring than on the spring with equal steps shown in Fig. 7, for we stress the main leaf more uniformly throughout its length, and so place a larger volume of metal at work; at the same time, the short leaf being longer, there is a greater total weight of metal in the spring, and actually the increase of strength is not in proportion to the extra weight of metal, for the increase of strength is only 4.1 per cent., while the increase of weight is 6.7 per cent.

TABLE V.

Strength of Springs.

EQUAL REACTIONS.

K	$p=1$	$p=2$	$p=3$	$p=4$	$p=5$	$p=6$
1	1.000	2.000	3.000	4.000	5.000	6.000
2	1.667	2.500	3.333	4.166	4.999	5.832
3	2.298	3.310	3.962	4.794	5.626	6.458
4	2.913	3.748	4.583	5.418	6.253	7.088
5	3.519	4.356	5.193	6.030	6.867	7.704
6	4.119	4.958	5.797	6.636	7.475	8.314
7	4.715	5.556	6.397	7.238	8.079	8.920
8	5.308	6.151	6.994	7.837	8.680	9.523
9	5.898	6.742	7.586	8.430	9.274	10.118
10	6.486	7.331	8.176	9.021	9.866	10.711
11	7.073	7.918	8.763	9.608	10.453	11.298
12	7.658	8.504	9.350	10.196	11.042	11.888
13	8.242	9.088	9.934	10.780	11.626	12.472
14	8.825	9.672	10.519	11.366	12.213	13.060
15	9.407	10.254	11.101	11.948	12.795	13.642
16	9.989	10.837	11.685	12.533	13.381	14.229
17	10.569	11.417	12.265	13.113	13.961	14.809
18	11.150	11.998	12.846	13.694	14.542	15.390
19	11.729	12.578	13.427	14.276	15.125	15.974
20	12.308	13.157	14.006	14.855	15.704	16.555

TABLE VI.

Deflection Coefficients.

EQUAL REACTIONS.

K	$p=1$	$p=2$	$p=3$	$p=4$	$p=5$	$p=6$
1	.3333	.1667	.1111	.0833	.0667	.0556
2	.1893	.1187	.0871	.0689	.0571	.0487
3	.1339	.0935	.0726	.0594	.0504	.0428
4	.1041	.0776	.0625	.0525	.0453	.0399
5	.0853	.0665	.0551	.0465	.0412	.0367
6	.0723	.0582	.0493	.0428	.0379	.0340
7	.0628	.0519	.0446	.0393	.0351	.0317
8	.0556	.0468	.0408	.0363	.0327	.0297
9	.0499	.0427	.0376	.0337	.0306	.0280
10	.0452	.0392	.0349	.0315	.0288	.0265
11	.0414	.0363	.0326	.0296	.0272	.0251
12	.0381	.0337	.0308	.0279	.0257	.0239
13	.0354	.0315	.0287	.0264	.0244	.0227
14	.0330	.0297	.0271	.0250	.0233	.0217
15	.0309	.0279	.0257	.0238	.0222	.0208
16	.0291	.0264	.0244	.0227	.0212	.0198
17	.0274	.0251	.0232	.0217	.0203	.0192
18	.0260	.0239	.0222	.0208	.0195	.0184
19	.0247	.0228	.0212	.0199	.0188	.0178
20	.0235	.0217	.0204	.0192	.0181	.0172

Observe in Fig. 9 that the *stresses are still the greatest in the short leaf*. It is impossible to alter this by merely changing the steps.

Irrigation in Quincy Valley, Washington. ANON. (U. S. Geological Survey, *Press Bulletin*, No. 343, November, 1917.)—One of the most interesting experiments ever made in the reclamation of the arid West is at present in progress in Quincy Valley, Washington, where well water is being pumped from maximum depths of 300 feet to irrigate apple orchards, and where, at one of the largest plants, about 1000 gallons a minute is recovered by means of a huge reciprocating pump from a single well in which the water stands about 230 feet below the surface. In order to ascertain more definitely the quantity of ground water available for pumping in this region, the United States Geological Survey, Department of the Interior, in response to requests and inquiries from many interested persons, recently investigated the ground-water conditions.

In 1916 about 4000 acres were irrigated in Quincy Valley, of which 3300 acres were supplied by water pumped from wells and 700 acres by water pumped from Moses Lake. The plants that pump water from wells have lifts ranging from 10 to 300 feet and capacities ranging from 25 to 1000 gallons a minute. With distillate costing 14 cents a gallon, the expense for fuel at 30 plants ranged from $1.50 to $18 per acre-foot of water pumped, the average being about $2 for an acre-foot lifted 50 feet. This cost could have been materially reduced by using distillate of lower grade.

Ground water for irrigation is obtained from three distinct formations—the basalt or lava beds, which supply water in the western part of the valley; the lake beds, which supply water in a belt extending through the central part of the valley, including the Morrison Flat; and the glacial-outwash deposits, which supply water in the eastern part of the valley, including the region adjacent to Crab Creek and Moses Lake.

The quantity of water in the basalt is large, and wells that yield several hundred gallons a minute obtain water from this formation. It is impossible to estimate closely the annual intake or the amount that can be recovered each year by pumping. There will no doubt be enough water to supply indefinitely the land now under irrigation, and experience may prove that considerably more land can be irrigated. However, the geologic and topographic conditions make it certain that the irrigation of the entire valley, or even of a large part of the area in which the wells end in basalt, is impossible. Moreover, these conditions indicate that it would be unwise at present to undertake irrigation projects aggregating more than a few thousand acres to be supplied from the water in the basalt.

Wells ending in the lake beds yield as much as 300 gallons a minute and furnish some water for irrigation. The water in the lake beds is derived from the same sources as that in the basalt and is not supplied to any important extent by Crab Creek or the glacial-outwash deposits.

It is estimated that the basalt, lake beds, glacial-outwash deposits, and Moses Lake will together afford enough water to irrigate each year as much as 15,000 acres in Quincy Valley. Experience may prove that the supply is adequate for a still larger acreage, but larger developments are not justified by the facts now available and must be regarded as unsafe. The most dependable supplies are those in the glacial-outwash deposits and in Moses Lake.

One of the features of the recent investigation was the accurate measurement of the depth to the water level in a large number of wells widely distributed throughout the valley. These measurements will make it possible in the future to determine the effects of pumping and to make more precise estimates of the ground-water supply.

SAG-TEMPERATURE CALCULATIONS OF TRANSMISSION LINES ON STEEP GRADES.*

BY

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THE men engaged in the erection of overhead electric power transmission lines should be provided with tables or charts giving the sag or tension at different temperatures for a given length of span. This enables them to string the wires—either by sighting from pole to pole when erecting to the required sag, or by using a dynamometer when erecting to the required tension—so that the stress shall not exceed the specified limit under the weather conditions which will produce the assumed maximum loading.

If the storm conditions are such as to produce in the wire a stress n times as great as the stress when the wire hangs in still air at the same temperature under the influence of gravity only, there will be a reduction in length due to elastic contraction when this extra load is removed, and the maximum deflection from the straight line joining the points of support will now be less than under storm conditions. It should, however, be observed that, with a sufficient rise of temperature, the elongation of the wire will be such as to produce the same maximum deflection notwithstanding a reduction in the tension. This particular temperature —which may be called the "critical" temperature—is very easily calculated,[1] and since the relation between sag and tension is expressed by the well-known formula,

$$s = \frac{wl^2}{8P} \tag{1}$$

it follows that, if s (the sag) and l (the span) remain constant, we obtain the relation

$$\frac{nw}{P} = \frac{w}{P_c}$$

or

$$P_c = \frac{P}{n} \tag{2}$$

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* Communicated by the Author.

[1] This calculation, together with formulæ for use in obtaining sag-temperature curves, are given in the writer's book, "Overhead Electric Power Transmission."

where nw is the loading per foot of wire producing the maximum tension P, and w is the loading in pounds per foot which produces the tension P_c when the temperature is such that the sag of the conductor hanging in still air is the same as the maximum deflection under storm conditions.

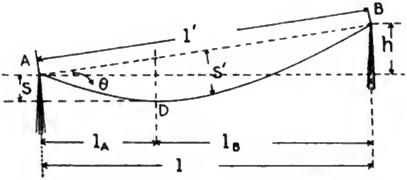
The sag at any other temperature will depend upon the length of the wire in the span, the connection between these quantities being given by the formula

$$\lambda = l + \frac{8s^2}{3l} \tag{3}$$

which is the approximate expression for the length of a parabolic arc.

When the points of support A and B (see Fig. 1) are not on the same level, but are so nearly at the same elevation that the lowest point (D) of the span lies somewhere between the two points of support, the length of wire may be considered as the sum of two half spans of lengths l_A and l_B respectively: this leads to the formula

FIG. 1.

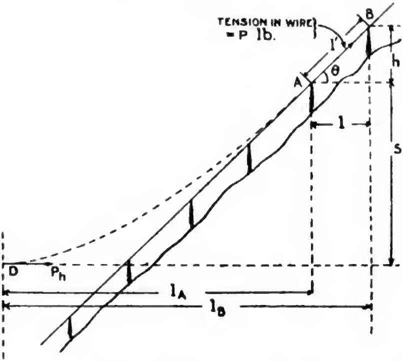


$$\lambda = l + \frac{2}{3}\left[\frac{(s+h)^2}{l-l_A} + \frac{s^2}{l_A}\right] \tag{4}$$

wherein the symbols correspond to the lettering of Fig. 1. By assuming different values of sag, s, the corresponding tension in the wire may be calculated by substituting $2l_A$ for l in formula (1), and the length of arc may be calculated by formula (4). Variations in the length of wire are due (a) to change of tension, (b) to change of temperature. The change in length due to cause (a) is known, because, for a given sag, the tension is known, and it follows that the change in temperature to produce such elongation or contraction as is not accounted for by change of tension can easily be calculated. This outline of the method of obtaining data for the plotting of sag-temperature curves will suffice to show that small errors in calculating the length of the wire may lead to serious errors in the final results.

The horizontal distance l_A from the lower support A to the point D where the wire is horizontal (see Fig. 1) is readily calculated by considering that at the point D, where the horizontal component of the tension is P_h, the vertical component is zero; while at a point half way between A and B the vertical component of the tension is P_h tan θ, or $P_h \times h/l$. This must be equal to the weight of a piece of wire of which the length is $\left(\frac{l}{2} - l_A\right)\frac{l'}{l}$ approximately. Thus

FIG. 2.



$$P_h \frac{h}{l} = w\left(\frac{l}{2} - l_A\right)\frac{l'}{l}$$

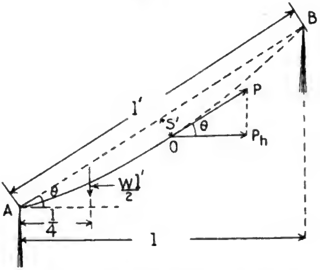
whence

$$l_A = \frac{l}{2} - \frac{hP_h}{wl'} \qquad (5)$$

Consider now Fig. 2, where the span $A\,B$ is supposed to be on a steep incline. If the formula (5) is used for calculating the distance l_A from the lower support A to the point where the wire becomes horizontal, this quantity will be negative. It will determine the shape and position of an imaginary parabolic curve as indicated by the dotted line of Fig. 2. The vertical component of the tension at the point B will be equal to the weight of the wire in the parabolic arc BD; while the vertical component at A will be the weight of the portion AD. The horizontal component (P_h) of the tension will be $P \cos \theta$, where P stands for the tension in the wire at the middle of the span AB.

Temperature-stress calculation can be made by considering the length of the wire in the span AB to be the difference between the imaginary half spans BD and AD, the procedure being exactly as indicated above. This method is, however, objectionable, because the required lengths are very small differences between comparatively large quantities, and unless several additional terms are added to the approximate formula for the length of the parabolic curve, serious errors may be introduced.

FIG. 3.



The alternative method about to be explained makes use of what may be thought of as an equivalent horizontal span.

Fig. 3 is an enlarged view of the span AB of Fig. 2. The deflection s' at the centre of the span may be calculated by taking moments about the point A. The pull P in the direction AB, acting at a distance s', is balanced by the weight ($\frac{1}{2}wl'$) of the half span AO, acting vertically downward at an average distance $\frac{l}{4}$, whence

$$Ps' = \frac{wl'}{2} \times \frac{l}{4}$$

and

$$s' = \frac{wl^2}{8\,P \cos} \qquad (6)$$

The maximum deflection s' of the wire from the straight line AB joining the points of support is always small relatively to the distance $l' = AB$; and in computing the length of a curve which approximates to a straight line, no appreciable difference will be observable, whether the curve be considered as part of a parabola, or catenary, or ellipse, or circle. For our purpose, it will be most convenient to calculate the length of the wire by using formula (3), merely substituting s' for s, and l' for l.

The method of procedure here recommended for the calculation of sag-temperature or tension-temperature data can therefore be summed up as follows: Consider the span of either Fig. 1 or Fig. 3 to be replaced by an equivalent horizontal span of length l', being the straight line distance between points of support, and of sag s' calculated by formula (6). Consider also that the vertical loading of this imaginary span is now $w \cos \theta$ pounds per foot run, distributed uniformly over the length l', and then proceed with the calculations exactly as in the case of spans having the two supports on the same level.

When the difference in levels is considerable, as in Fig. 3, the proper correction must be made in calculating the factor n. Thus, if w is the weight per foot of the wire (ice loading neglected) and p is the maximum (horizontal) wind pressure per foot of wire, the resultant load under storm conditions will be $\sqrt{w^2 + p^2}$, and the value of n as previously defined will be

$$n = \frac{\sqrt{w^2 + p^2}}{w} \tag{7}$$

for horizontal spans. When the angle of slope, θ, becomes so large that $\cos \theta$ differs appreciably from unity, we must write

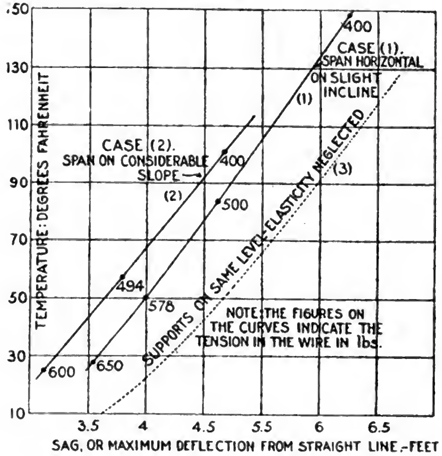
$$n = \frac{\sqrt{(w \cos \theta)^2 + p^2}}{w \cos \theta} \tag{8}$$

which is the value to be used in formula (2) when calculating the "critical" tension P_c from the assumed or specified permissible maximum tension P.

Space does not permit of the complete working out of a numerical example; but the results of some calculations on a practical line have been plotted in Fig. 4.

The assumptions as to distance between supports, maximum load, etc., are such as would be normal—even if unreasonable—in England, where the regulations governing factors of safety and construction details are not such as to encourage the development of power transmission by overhead conductors. The reason for choosing data based on British rather than on American practice will be explained later.

FIG. 4.



Data for calculation of results given in Fig. 4:

Wire: No. 0 B. & S. solid copper. (This is almost exactly the same size as No. 0 S. W. G.)

Diameter of wire, $d = 0.325$ in.
Cross-sectional area of wire, $A = 0.083$ sq. in.
Weight of wire per foot, $w = 0.32$ lb.
Distance between supports measured horizontally, $l = 195$ ft.
Difference of elevation between points of support, $h = 140$ ft.
whence, Distance between supports measured on slope, $l' = 240$ ft.
Breaking stress (say) 55,000 lb. per sq. in.
Factor of safety $= 5$.

Maximum wind pressure = 15 lb. per sq. ft. of projected area of wire.

Temperature at which maximum wind pressure occurs, $t = 22°$ F.

The curve marked (2) in Fig. 4 gives the relation between temperature and deflection (s') which can be measured by sighting from pole to pole on the incline. The figures on the curve are the tensions corresponding to particular temperatures. Tensions for intermediate points can very quickly be calculated by means of formula (6) if it is desired to erect the conductors with a dynamometer rather than by measuring the dip.

The curve marked (1) refers to the same span placed horizontally; that is to say, with the points of support 240 feet apart on the same level. In both cases the specified limiting tension in the wire will be reached at a temperature of 22° F., with maximum wind-pressure in a direction perpendicular to the vertical plane passing through the points of support.

The dotted curve marked (3) in Fig. 4 is plotted from the same data as curve (1), except that the effect due to the elasticity of the wire has been neglected. The omission is often permissible, especially on long spans of aluminum wire; but on comparatively short spans of copper wire, as in the present instance, it is seen to give inaccurate results. The point has been referred to because of the peculiarity that in England—where the stringent regulations involving large factors of safety necessitate uneconomical construction with short spans—it is by no means uncommon to neglect the elasticity of the wire; while in America—where the longer spans are the cause of reduced stress variations—it is customary to take account of the changes in length due to variation of load.

Methods of Gas Warfare. S. J. M. AULD. (*Journal of the Washington Academy of Sciences,* vol. 8, No. 3, p. 45, February 4, 1918.)—Not so much is heard of gas warfare at the present time as two years ago, when the first use of that method of attack was made on the Western Front. Gas is, however, used to a tremendous extent, and the amount that has been and is being hurled back and forth in shells and clouds is almost unbelievable. The success of a cloud gas attack depends on thorough preparation beforehand. The attackers must know the country, the layout of the trenches, and the direction and velocity of the wind with certainty. Favorable conditions are limited practically to wind velocities between twelve and fourteen miles per hour, with no upward currents. German gas attacks are made by two regiments of Pioneers, with highly technical officers, including engineers, meteorologists, and chemists.

The first attack was made with chlorine. If a gas attack is to be made with gas clouds, the number of gases available is limited. The gas must be easily compressible, easily made in large quantities, and should be considerably heavier than air. If to this is added the necessity of its being very toxic and of low chemical reactivity, the choice is practically reduced to two gases—chlorine and phosgene. The gas is contained in an ordinary cylinder like that used for oxygen or hydrogen. Pure chlorine did not satisfy quite all the requirements, as it is very active chemically and, therefore, easily absorbed. Pads soaked in solutions of sodium carbonate and thiosulphate were first used in the protective respirators. Later, with the introduction of phosgene, a gas which is very insidious and difficult to protect against sodium phenate was used.

There are so many conditions that have to be fulfilled in connection with the gas cloud that its use is limited. The case is different with gas shells. The gas shells are the most important of all methods of using gas on the Western Front, and are still in course of development. The first use of this method was with the celebrated " tear " shells. A concentration of one part in a million of some of these lachrymators makes the eyes water severely. The original tear shells contained almost pure xylyl bromide or benzyl bromide, made by brominating the higher fractions of coal-tar distillates. Another substance used in shells which simultaneously harasses and seriously injures is dichloro-diethylsulfide (mustard gas). It has no immediate effect on the eyes beyond a slight irritation. After several hours the eyes begin to swell and inflame and practically blister, causing intense pain, the nose discharges freely, and severe coughing and even vomiting ensue. The Germans have also used phenylcarbilamine chloride, a lachrymator, and diphenylchlorarsine, or " sneezing gas." The latter is mixed with high explosive shells or with other gas shells, or with shrapnel. It was intended to make a man sneeze so violently that he is unable to wear his mask. The sneezing gas has, however, not been a very great success.

Up to the present time there has been no material brought out on either side that can be depended upon to penetrate the respirator. The casualties are due to surprise or to lack of training in the use of masks. The mask must be put on and adjusted within six seconds, which requires a considerable amount of preliminary training if it is to be done under field conditions. Both sides are trying to find something the others have not used, and both are trying to find a " colorless, odorless, and invisible " gas that is highly poisonous. It is within the realm of possibility that the war will be finished literally in the chemical laboratory.

PHYSICS OF THE AIR.*

BY

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CHAPTER XII.

EVAPORATION AND CONDENSATION.

INTRODUCTION.

THE presence of water vapor in the atmosphere is of such vital importance in the economy of Nature, and the source of so many phenomena, as to demand a study of, among other things: evaporation, by which the vapor is gotten into and rendered a portion of the atmosphere, mainly from free surfaces, but also from vegetation and damp soil; and condensation, by which in various forms it is removed from the air.

EVAPORATION.

Evaporation, the process by which a liquid becomes a vapor, or gas, is a result of the kinetic energy of the individual molecules. Some of the molecules at or near the surface have such velocities and directions that they escape from the liquid and thus become an integral part of the surrounding gas or atmosphere; and as the chance of escape, other things remaining equal, increases with the velocity, it follows (*a*) that the average kinetic energy of the escaping molecules is greater than that of the remaining ones, or that evaporation decreases the temperature of a liquid, and (*b*) that the rate of evaporation increases with increase of temperature.

Just as the kinetic energy of some of the molecules of the liquid carries them into the space about, so, too, the kinetic energy of some of the molecules of the gaseous phase causes them to penetrate into and thus become a part of the liquid. In reality, therefore, evaporation from and condensation onto the surface of a liquid, though necessarily taking place by discrete molecular units, practically are continuous processes whose ratio may have any value whatever. As popularly used, however, and even as very commonly used scientifically, the term "evaporation" refers to the net loss of a liquid, and "condensation" to its net gain, so that, in this sense, both are said to be zero when, as a matter of fact, they are only equal to each other.

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* Continued from page 372, vol. 185, March, 1918.

In the sense of net loss, which admits of accurate measurement, evaporation has been the subject of numerous investigations. Vegetation, soil, and the free water surface each offers its own peculiar and numerous evaporation problems. In what follows, however, only the free surface will be considered.

Evaporation into Still Air (a) from Tubes.—The rate of loss of a liquid by evaporation and diffusion, through a tube of fixed length and constant cross-section, into a still atmosphere has been carefully studied by Stefan.[68] Obviously, when a steady state has been attained, the rate at which the vapor escapes per unit area of the cross-section of the tube is constant, directly proportional to the driving force and inversely proportional to the resistance. These in turn are proportional, respectively, to the pressure gradient of the vapor along the tube and the partial pressure of the foreign gas at the same place. In symbols,

$$v = -\frac{k}{P-p}\frac{dp}{dn} = k\frac{d}{dn}\log(P-p),$$

in which v is the volume at 0° C. and 760 mm. pressure of the vapor that escapes per second per unit area of the cross-section of the tube, P the total pressure, a constant, $\frac{dp}{dn}$, the vapor pressure gradient along the tube at and normal to the cross-section at which the partial pressure due to the vapor is p, and k the coefficient of diffusion, whose value depends upon the nature of the vapor and the gas through which it is passing, and their temperature.

But as a steady state is assumed, it follows that both the rate of flow and the coefficient of diffusion k are independent of the distance n along the tube above the liquid surface. Hence,

$$V = \frac{kA}{h}\log\frac{P-p''}{P-p'}$$

in which V is the rate of total evaporation, A the area of the cross-section of the tube, h its height, or the distance of its top (tube supposed vertical) above the liquid, p'' and p' the partial pressures of the vapor at the free end and evaporating surface, respectively.

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[68] *Sitzungsberichte der K. Akad. der Wis. Wien*, 68 (1873), 385–423.

All the terms in this equation except k may easily be measured, and thus k itself evaluated. But with k known, the rate of evaporation of the same liquid (water, say) from a circular tube or well of any given cross-section and length, provided the length is equal to or greater than the diameter, may be computed from the total gas pressure and the vapor pressures at the surface of the liquid and top of the tube.

Evaporation into Still Air (b) from Flush Circular Areas.—The rate of evaporation into still air from a circular tank or pond filled flush with a relatively extensive plane which itself neither absorbs nor gives off any vapor has also been found by Stefan[69] susceptible of complete analysis.

From the general equation

$$v = -\frac{k}{P-p}\frac{dp}{dn}$$

it follows that

$$v = -k\frac{d}{dn}\log\frac{P-p_0}{P-p}$$

in which p_0 is the constant partial pressure of the vapor, during a steady state, at a given point. Hence if

$$u = \log\frac{P-p_0}{P-p}$$

$$v = -k\frac{du}{dn}$$

But this is identical with the flow of heat when $\frac{du}{dn}$ is the temperature gradient and k the thermal conductivity. Similarly it represents the flow of electricity, and also the field of force in the presence of a charged plate. If σ is the density of the surface charge on a plate, then

$$-\frac{du}{dn} = 4\pi\sigma.$$

Further, if E is the total charge,

$$E = Cu_1$$

in which C is the capacity of the plate and u_1 its potential. Hence the total diffusion, confined to *one* side, is given by the expression

$$V = 2\pi kCu_1$$

But

$$u_1 = \log\frac{P-p_0}{P-p_1}$$

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[69] *Sitzungsberichte der K. Akad. der Wis. Wien*, 73 (1881), 943–954.

in which p_0 is the vapor pressure of the free air at a great distance from the evaporating surface and p_1 its pressure at the surface, or saturation pressure at the surface temperature.

The capacity of a circular disk of radius a is

$$C = \frac{2a}{\pi}$$

Hence

$$V = 4ak \log \frac{P - p_0}{P - p_1}$$

If p_0 and p_1 are both small in comparison to P,

$$V = 4ak \frac{(p_1 - p_0)}{P}, \text{ nearly.}$$

The real importance of this equation is its proof that evaporation, under the restricted conditions assumed, is proportional to the *diameter* (or other linear dimension) of the evaporating surface and *not,* as one might suppose, to its area. Obviously, therefore, evaporation in the open under ordinary conditions cannot be directly proportional, as often assumed, to the area involved.

Evaporation into Still Air (c) from Elliptical Areas.—Evaporation from an elliptical surface is slightly faster than from a circular one of equal area, but the difference is small until the major axis of the ellipse becomes several times longer than the minor; being only 1.11 as fast when the ratio of the axes is 1 to 4. Hence, when the axes do not greatly differ, a close approximation to the rate of evaporation from an elliptical surface is given by the equation

$$V = 4\sqrt{ab}\, k \log \frac{P - p_0}{P - p_1},$$

or, when p_0 and p_1 are small with reference to P,

$$V = 4\sqrt{ab}\, k \frac{p_1 - p_0}{P}$$

No exact mathematical expression has yet been obtained for the rate of evaporation into still air from surfaces of any other outline than the above—circle and ellipse—nor from either of these under outdoor conditions.

Evaporation in the Open.—Several hundred papers,[70] many of them giving the results of elaborate investigations, have been published on the evaporation of water from free surfaces, vegetation, and soil, and, while no equation has been found that expresses in terms of easily measurable quantities the rates of evaporation in the open, nevertheless several factors that control these rates have been discovered and more or less approximately evaluated. In the case of free, clean surfaces the principal factors are:

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[70] Livingston, "An Annotated Bibliography of Evaporation," M. W. R., June, September, and November, 1908, and February, March, April, May, and June, 1909.

(a) *Salinity.*—It has repeatedly been observed that the evaporation of salt solutions decreases with increase of concentration, and that sea-water evaporates approximately 5 per cent. less rapidly than fresh water under the same conditions.

(b) *Dryness of the Air.*—Many observations have shown that, to at least a first approximation, the rate of evaporation is directly proportional, other things being equal, to the difference in temperature indicated by the wet and dry bulb thermometers of a whirled psychrometer.

According to the psychrometric formula developed by Apjohn, Maxwell, Stefan, and others,

$$p_1 - p_0 = AB(t_0 - t_1)$$

in which t_0 is the temperature and p_0 the vapor pressure of the free air, t_1 the temperature of the wet bulb (and surface of evaporating liquid), p_1 the saturation vapor pressure at temperature t_1, B the barometric pressure, and A a constant, provided ventilation is sufficient. But evaporation is proportional to the ratio of vapor pressure gradient to total pressure; that is,

$$V = k\frac{p_1 - p_0}{B}$$

Hence, other things being equal,

$$V = C\ (t_0 - t_1), \text{ approximately.}$$

But $t_0 - t_1$ increases with the dryness, and hence so does evaporation.

(c) *Velocity of the Wind.*—All observers agree that evaporation increases with wind velocity, presumably through increase of the vapor pressure gradient, but the exact rate is not certain. At low velocities the effect is very great, while at 4 metres per second and considerably higher it appears to be roughly proportional to the velocity.

(d) *Barometric Pressure.*—Since the presence of any gas retards the diffusion of other gas molecules, whether of the same or different nature, it follows that when the vapor tension is comparatively small evaporation must vary inversely, nearly, as the total barometric pressure.

(e) *Area of Surface.*—Obviously the total amount of water evaporated must increase with the area of the evaporating surface, but not necessarily at the same rate. In fact, as already explained, if the evaporation is from a circular area into still air, it increases as the square root of the area. Under outdoor conditions, however, it is much more nearly, though probably by no means exactly, proportional to the total surface.

(f) *Temperature of the Water.*—Evaporation increases rapidly with the temperature of the water, roughly in proportion to the saturation pressure at that temperature, provided the general humidity of the air is low. When, however, the water surface is colder than the dew-point temperature of the air the evaporation becomes negative; that is, condensation obtains. When the air is colder than the water surface, evaporation may continue into it after saturation has been reached and thereby produce fog, the process being one of distillation and condensation.

Even when the water is frozen, it still continues slowly to evaporate (sublime) whenever the air is sufficiently dry, but the laws governing this sublimation are not well known.

Empirical Evaporation Equations.—Various equations, each at least partially empirical, have been devised to fit evaporation data obtained under special conditions. But the " constants " of these equations generally are not constant under other circumstances. Indeed, it may be that no simple equation of this kind, applicable to a wide range of conditions, is possible, and that therefore the most expeditious way to obtain useful evaporation data would be to note the daily, monthly, annual, etc., loss from standard exposures in each climatic region, and, wherever practical, to supplement such data by similar observations on lakes, ponds, and reservoirs. Controlled wind-tunnel experiments would also be interesting and useful.

One of the earliest experimenters to make a careful study of evaporation was John Dalton,[71] who says:

1. " Some fluids evaporate much more quickly than others."

2. " The quantity evaporated is in direct proportion to the surface exposed, all other circumstances alike."

3. " An increase of temperature in the liquid is attended with an increase of evaporation, not directly proportionable."

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[71] *Mem. Manchester Lit. and Phil. Soc.*, 5, 574, read October, 1801.

4. "Evaporation is greater where there is a stream of air than where the air is stagnant."

5. "Evaporation from water is greater the less the humidity previously existing in the atmosphere, all other circumstances the same."

All these are important observations, but they do not fully justify the so-called Dalton equation which Dalton himself apparently never wrote.

Weilenmann and Stelling, working independently and at different places, obtained evaporation equations of the general form[72]

$$\frac{dn}{dt} = (cb + kw)\ (p_s - p_0)$$

in which c and k are constants, b the barometric pressure, w the wind velocity, p_s the saturation vapor pressure at the temperature of the water surface, and p_0 the actual vapor pressure in the free air at some distance from the water.

Fitzgerald[73] finds the rate of evaporation, E, in inches per hour, given approximately by the equation

$$E = \frac{(p_s - p_0)\ (1 + 1/2w)}{60}$$

in which p_s and p_0 have the meanings, respectively, given above, and w is the average wind velocity in miles per hour.

Various other equations have been found or proposed, but they either contain unevaluated functions or else were constructed to fit a special set of observations. The multiplicity of such equations, each of but limited use, emphasizes the difficulty of the evaporation problem, if not even the impossibility of finding for it a practical, universal equation.

CONDENSATION.

Condensation, the process by which a vapor is reduced to a liquid or solid, is induced by: (*a*) reduction of temperature, volume remaining constant; (*b*) reduction of volume, temperature remaining constant; (*c*) a combination of temperature and volume changes that jointly reduce the total vapor capacity. In the open, water vapor is condensed: (1) by contact cooling; (2) by the mixture of masses of air of unequal temperatures; (3) by expansional or dynamic cooling due to vertical convection, or, occasionally, other causes, especially rotation, as in tornado and waterspout funnels.

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[72] Hann, "Lehrbuch der Meteorologie," 3d edition, p. 214.

[73] *Trans. Amer. Soc. Civ. Eng.*, 15 (1886), 581–645.

Condensation Due to Contact Cooling.—During clear nights the surface of the earth, including vegetation and other objects, loses much heat by radiation, and thus both it and the air in contact with it are reduced to lower temperatures, obviously more pronounced the gentler the winds. After the dew-point has been reached all further loss of heat, producing now a much smaller proportionate decrease of temperature, results in the deposition, respectively, of dew and hoar-frost at temperatures above and below freezing. Similarly, relatively warm, moist air moving over a snow bank, for instance, may deposit some of its moisture.

In any typical case of surface cooling the deposition of dew, say, is caused partly by temperature reduction and partly by decrease of volume. Let the air, saturated at the absolute temperature T_o, be cooled, without change of volume, to T_1, and let the water vapor per unit saturated volume at these temperatures be w_o and w_1, respectively. Then the quantity of water, $w_o - w_1$, will be deposited per unit volume as a result of cooling alone, while if the pressure remains constant, as it does, approximately, the volume will be reduced in the proportion

$$\frac{V_o}{V_1} = \frac{T_o}{T_1}$$

and an additional quantity of water

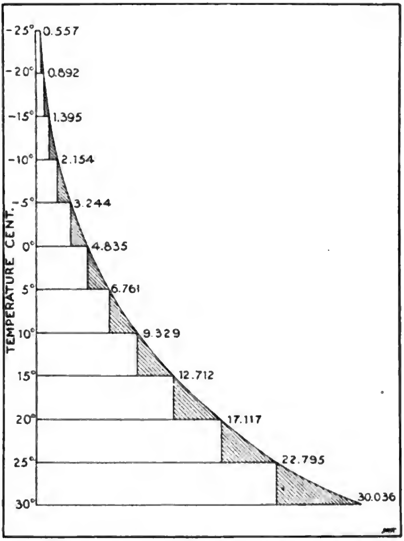
$$w_1 \frac{T_o - T_1}{T_o}$$

deposited per unit volume at temperature T_o. Hence the quantity q of water deposited per original unit volume due to both processes combined, decrease of temperature and decrease of volume, is given by the equation

$$q = w_o - w_1 \frac{T_1}{T_o}.$$

Condensation Due to Mixing.—Since the amount of water vapor per saturated unit volume decreases with temperature more rapidly than the absolute temperature itself, at least through the range of atmospheric temperatures (see Fig. 58), it follows that the mixture of two saturated masses of air of unequal temperatures must produce some precipitation. The amount of precipitation induced in this manner, however, is surprisingly small; indeed, it seldom can be sufficient to produce more than a light cloud or fog. If the resulting temperature were the proportionate mean of the known temperatures of the quantities of air mixed, the amount of precipitation could easily be computed from the initial humidities. But the latent heat of the condensation prevents this simple relation from obtaining, so that the actual amount of precipitation can better be determined graphically than by direct calculation.[74] To this end use a humidity temperature curve, such as Fig. 59, drawn to scale. For example, let equal masses of saturated air at 0° C. and 20° C. be mixed at normal pressure—certainly an extreme case. As a first approximation it may be assumed that the final temperature is 10° C., and, since there are 3.75, 7.52, and 14.34 grammes of water vapor per 1000

FIG. 58.



Grammes of water vapor per saturated cubic metre, at different temperatures. Bases of shaded portions proportional to precipitations per 5° C. cooling from the temperatures indicated grammes of saturated air at normal pressure and 0° C., 10° C., and 20° C., respectively, the precipitation per 1000 grammes of the mixed air would seem to be

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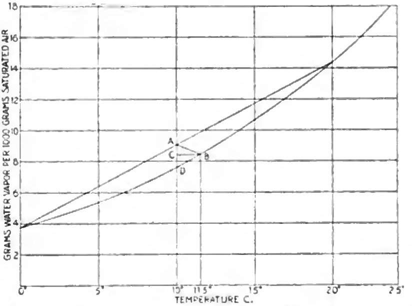
[74] Hann, "Lehrbuch der Meteorologie," 3d edition, p. 249.

$$\frac{3.75+14.34}{2}-7.52=1.53 \text{ grammes,}$$

represented by *AD* in the figure.

But the latent heat of condensation causes the final temperature to be above the average, and the amount of precipitated water, therefore, less than that just computed. But since the latent heat of vaporization at 10° C. is approximately 600 calories per gramme, and the specific heat of the air at constant pressure about 0.24, it follows that the warming of the air will be at the rate of 2.5° C. per gramme of water vapor condensed from each 1000 grammes of air. Hence a second approximation to the final temperature and condensation is found by drawing from *A* a line in such direction that it shall indicate a change of 2.5° C. per gramme of condensate, and prolonging it until it meets the humidity temperature curve in *B*. This second approximation gives 11.5° C. very closely, instead of 10° C., as the temperature of the mixture, and 0.6 gramme, instead of 1.53 grammes, as the amount of condensation per 1000 grammes of air, a quantity which, as the figure shows, would be condensed by a temperature decrease of less than 1° C.

Fig. 59.



Precipitation due to the mixing of saturated equal masses of warm and cold air.

Obviously similar graphical solutions may easily be made for mixtures of unequal masses of air, for unsaturated air, for other pressures, and for other temperatures; though for temperatures slightly below 0° C. a greater latent heat of vaporization, approximately 680, must be used.

Since 1000 grammes of saturated air at 10° C. and normal pressure occupies very approximately $\frac{25}{31}$ of a cubic metre, it follows that the condensation above described is about 0.74 gramme per cubic metre, a quantity capable of producing only a light cloud through which objects would be visible to a distance of about 70 metres.[75] Further, assuming the diameter of each cloud particle to be 0.033 mm., Wagner's average value, it follows that the condensation in question could produce only about 39 such fog particles per cubic centimetre.

Even if such a cloud were 1 kilometre thick and all its droplets should be brought down, they would produce a water layer only 0.074 cm. deep. Obviously, therefore, the mere mixing of masses of humid air at different temperatures cannot produce any appreciable precipitation in the form of rain or snow.

Condensation Due to Dynamic Cooling.—Dynamic cooling incident to vertical convection is by far the most effective method of inducing precipitation, but even when the convection is adiabatic it is not immediately obvious, from the initial temperature, humidity, and pressure, just how much water will be precipitated as the result of a given increase of altitude, nor even for a given decrease of temperature. This is because the rate of cooling with elevation is affected by the latent heat of vaporization, and the amount of condensation in turn decreased by the increase of volume, which itself is a function of the temperature and pressure. The problem is further complicated, on passing to temperatures below 0° C., by the latent heat of fusion and by the abrupt considerable change in the heat of vaporization.

It therefore will be convenient to consider independently four possible stages in the dynamic cooling of a quantity of moist air: (*a*) the unsaturated; (*b*) the saturated at temperatures above 0° C.; (*c*) the freezing; and (*d*) the saturated at temperatures below 0° C.

This subject has been studied by several investigators, especially Hann,[76] Guldberg and Mohn,[77] Hertz,[78] and Neuhoff.[79] Of these Neuhoff's paper appears to be the most explicit, and it therefore will be used as the basis of the following brief discussion.

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[75] Wagner, *Sitz. der K. Akad. der Wis. Wien*, 117 (1908), p. 1290.

Dry (Unsaturated) Stage.—Let the humidity be such that the mass ratio of dry air to water vapor is $1:w$. Then the number of calories, dQ, necessary to change the temperature of $1+w$ grammes of this atmosphere by dT and its volume by dV is given by the equation

$$dQ=(C_v+wC'_v)dT+ApdV,$$

in which C_v and C'_v are the specific heats at constant volume, respectively, of dry air and *unsaturated* water vapor, A the reciprocal of the mechanical equivalent of heat, and p the pressure.

But, for n grammes,

$$pV=nRT,$$

in which R is the well-known gas constant and T the absolute temperature, numerically, 273+ reading of centigrade thermometer. Hence,

$$dQ=(C_v+wC'_v)dT+(R+wR')AT\frac{dV}{V}$$

Since pressures in the open air are easily measured, while volumes are not, it will be more convenient to have this equation expressed in terms of the former. This may be done by substitutions from the equations

$$pdV+Vdp=RdT$$

and

$$C_v=C_p-AR$$

in which C_p is the specific heat at constant pressure.

If the convection is adiabatic—that is, if

$$dQ=0$$

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[76] *Met. Zeit.*, 9 (1874), 321, 337.

[77] "Etudes sur les Mouvements de l'Atmosphère," part 1, Christiania, 1876, revised 1883; translation by Abbe, "Mechanics of the Earth's Atmosphere." Smithsonian Institution, 1910.

[78] *Met. Zeit.*, 1 (1884), p. 421; translation by Abbe, "Mechanics of the Earth's Atmosphere," Smithsonian Institution, 1891.

[79] *K. Prus. Meteor. Inst.*, 1 (1900), p. 271; translated by Abbe, "Mechanics of the Earth's Atmosphere." Smithsonian Institution, 1910.

these substitutions give the equation

$$(C_p+wC'_p)\frac{dT}{T}=A(R+wR')\frac{dp}{p},$$

or, by integration,

$$(C_p+wC'_p)\log\frac{T}{T_0}=A(R+wR')\log\frac{p}{p_0},$$

or, more simply,

$$\log\frac{p}{p_0}=K\log\frac{T}{T_0},\ K=\text{a constant},$$

in which p_0 and T_0 are, respectively, the initial surface pressure and temperature.

Obviously this equation is applicable only until saturation is attained.

Let e_0 and e be, respectively, the initial and saturation vapor pressures corresponding to the total pressures p and p, and absolute temperatures T_0 and T.
Then

$$\log\frac{e}{e_0}=K\log\frac{T}{T_0}$$

and

$$\log e-K\log T=\log e_0-K\log T_0=C,\ \text{a constant.}$$

If e_0 and T_0 are both known, C is also known, and since saturation vapor pressure depends upon temperature alone, and is known through a wide temperature range, it is obvious that both $\log e$ and $K\log T$ may be tabulated for many values of T, and that with such a table it is easy to pick out that value of T which gives the equation

$$\log e-K\log T=C,$$

the equation that determines the limit of the non-saturated or dry stage.

If the convection has been adiabatic it is obvious that the height h of the dry stage is given by the equation

$$h=100\,(T_0-T)\ \text{metres, approximately.}$$

It should be distinctly noted that in general vertical convection does not follow a fixed plumb-line. In cyclonic areas, for instance, the horizontal travel of the air doubtless often is hundreds of times the vertical. Hence in the quadrant of such a region where the clouds are from lower latitudes the vertical temperature gradient at any given place is likely to indicate a greater departure from adiabatic expansion than actually has occurred. This, as explained, is because the proper p_0 and T_0 to use in the above equations are those that obtained when and where the mass of air in question started to rise, and not those at the surface beneath its position at the time for which the equations are given.

Under such circumstances the true values of p_0 and T_0 are not accurately known, but that does not affect the validity of the above discussion; it only emphasizes the complexity of the problem as frequently presented in Nature.

Rain (Saturated, Unfrozen) Stage.—After saturation has been attained any further convectional cooling leads to precipitation. It will be assumed that this water is carried along with the ascending current (never strictly true and less nearly so as the drops grow in size), thus leaving the process adiabatic and reversible, and that the volume of the liquid water is negligible in comparison to the space from which it was condensed.

Let p be the total pressure, made up of the two partial pressures, air pressure p' and saturated water vapor pressure e, a function of the temperature alone, and let the mass ratio of air to total water, condensed and uncondensed, be 1 : w. Then

$$p = p' + e = \frac{RT}{V} + e.$$

As before, the quantity of heat necessary to change the temperature of 1 gramme of air by an amount dT and its volume by dV is

$$dQ' = \left(C_v dT + ART\frac{dV}{V}\right).$$

Let w' be the grammes of uncondensed water vapor per gramme of dry air. Then $w - w'$ is the corresponding number of grammes of liquid water. Hence the heat necessary to bring about the temperature change dT and the vapor change dw' is

$$dQ'' = w' s_2 dT + (w - w')\, s_1 dT + L dw'$$

in which s_2 is the specific heat of *saturated* water vapor (that is, its specific heat when the volume so changes with the temperature as to maintain saturation and avoid condensation—a negative quantity), s_1 the specific heat of water, and L the latent heat of vaporization.

With T constant,

$$dQ'' = L\,dw' = Td\phi, \quad \text{or,} \quad \left(\frac{d\phi}{dw'}\right)_T = \frac{L}{T}, \ \phi \text{ being entropy.}$$

With w' constant,

$$dQ'' = w's_2dT + (w-w')\,s_1dT = Td\phi, \quad \text{or,} \quad \left(\frac{d\phi}{dT}\right)_{w'} = \frac{s_1(w-w')+s_2w'}{T}$$

But dQ is a perfect differential, therefore

$$\frac{d}{dw'}\left(\frac{s_1(w-w')+s_2w'}{T}\right) = \frac{d}{dT}\left(\frac{L}{T}\right)$$

and

$$(s_2-s_1) = T\frac{d}{dT}\left(\frac{L}{T}\right)$$

Hence

$$dQ'' = ws_1dT + T\frac{d}{dT}\left(\frac{Lw'}{T}\right)dT,$$

and

$$dQ = \left(C_vdT + ART\frac{dV}{V}\right) + T\frac{d}{dT}\left(\frac{Lw'}{T}\right)dT + ws_1dT.$$

$$= \left(C_pdT - ART\frac{dp'}{p'}\right) + T\frac{d}{dT}\left(\frac{Lw'}{T}\right)dT + ws_1dT.$$

Hence, since the process is adiabatic,

$$(C_p + ws_1)\frac{dT}{T} + \frac{d}{dT}\left(\frac{Lw'}{T}\right)dT = AR\frac{dp'}{p'}.$$

By integration, using the subscript o for initial conditions,

$$\log\frac{p'}{p'_o} = \frac{C_p+ws_1}{AR}\log\frac{T}{T_o} + \frac{M}{AR}\left(\frac{Lw'}{T} - \frac{L_ow'_o}{T_o}\right)$$

in which M is the modulus of the system of logarithms used.

But

$$w' = \frac{Re}{R'p'}$$

Therefore

$$\log\frac{p'}{p'_o} = \frac{C_p+ws_1}{AR}\log\frac{T}{T_o} + \frac{M}{AR'}\left(\frac{eL}{p'T} - \frac{e_oL_o}{p'_oT_o}\right) = b\log\frac{T}{T_o} + \left(\frac{a}{p'} - \frac{a_o}{p'_o}\right).$$

in which b, a, and a_0 obviously are determinable numerical quantities for given values of w, T, and T_0.

Hence

$$\log p' - \frac{a}{p'} - b \log T = \log p'_0 - \frac{a_0}{p'_0} - b \log T_0 = \text{a constant.}$$

From this equation a table may be constructed giving the relation between p' and T, and also, since e is known through a wide range of temperatures, between p and T. The value of w', or grammes of water per gramme of dry air, is given for any temperature by the equation,

$$w' = \frac{Re}{R'p'},$$

and the condensed water, w'', per gramme of dry air by the equation,

$$w'' = w - \frac{Re}{R'p'}.$$

Hail (Freezing) Stage.—Further lowering of the pressure beyond that at which the temperature reaches 0° C. causes, so long as there is any liquid water present, both freezing and evaporation. The latent heat of fusion keeps the temperature constant, while the increase of volume under the reduced pressure increases the vapor capacity and thus leads to evaporation.

To each gramme of dry air let there be w, w', and w'' grammes, respectively, of water, vapor, and ice. Then, as there is no change of temperature through this stage,

$$dQ = ART_0 \frac{dV}{V} + Ldw' - Fdw''$$

in which F is the latent heat of fusion, and T_0 the absolute temperature at 0° C. The negative sign is used because the heat of fusion is added, or becomes sensitive with freezing; that is, with decrease of pressure and increase of volume.

Assuming the process adiabatic, dividing by T, as before, and integrating, the above equation reduces to

$$\frac{AR}{M} \log \frac{V_1}{V_0} + \frac{L}{T_0}(w'_1 - w'_0) - \frac{F}{T_0}(w''_1 - w''_0) = 0.$$

Let the subscript o indicate the condition when the temperature reaches 0° C. with no ice, and subscript 1 the condition when all the water is just frozen. As the temperature is constant, e

will be the same at the beginning and end of the freezing process. At the end of the freezing $w''_1 = w - w'_1$.

Also,

$$\frac{V''}{V_o} = \frac{p'_o}{p'_1};\ w'_o = \frac{R}{R'}\,\frac{e}{p_o - e};\ w'_1 = \frac{R}{R'}\,\frac{e}{p_1 - e};\ \text{and } w''_o = 0.$$

Hence

$$\log p'_1 - \frac{e}{p'_1}\,\frac{M(L+F)}{AR'T_o} = \log p'_o - \frac{e}{p'_o}\,\frac{M}{AR'}\,\frac{L}{T_o} - w\,\frac{M}{AR}\,\frac{F}{T_o}$$

This equation gives, in terms of known quantities, the relation between the partial pressures of the air at the beginning and end of the "hail stage," and therefore the depth of this stage, obviously determined by the amount of water to be frozen, which in turn depends on the original temperature and humidity.

Snow (Frozen) Stage.—At temperatures below 0° C. there will be present in the air only ice and enough water vapor to produce saturation. Hence the discussion applicable to this stage is identical with that for the "rain stage," though two of the constants, specific heat and latent heat, will be different. The specific heat is now of ice, roughly one-half that of water, while the total latent heat is due to two distinct processes, fusion and vaporization. The equation, therefore, applicable to the snow stage is,

$$\log \frac{p'}{p'_o} = \frac{C_p + ws_i}{AR} \log \frac{T}{T_o} + \frac{M}{AR'}\left(\frac{e(L+F)}{p'T} - \frac{e_o(L_o + F_o)}{p'_o T_o}\right)$$

in which s_i is the specific heat of ice, and the other terms have the meanings previously given.

It will be interesting to note that the form of the adiabatic equation is:

1. For the dry stage,

$$\log p - a \log T = C, \text{ a constant.}$$

2. For a condensation stage,

$$\log p' - \frac{b}{p'} - a \log T = K, \text{ a constant,}$$

in which a and b are numerical coefficients, p the total pressure, and p' the partial air pressure.

The short hail or freezing stage is distinct from either of the others, though it may be represented approximately by an equation of the second or condensation type.

"Pseudoadiabatic" Convection.—Adiabatic expansion of the atmosphere obviously implies that all cloud particles, rain drops, and snowflakes are carried along with the identical air in the midst of which they were condensed. This condition cannot rigorously obtain in Nature at any level; neither do all the products of condensation, especially the smaller droplets, rapidly fall away immediately they are formed. Hence the actual process, if conduction, radiation, and absorption were negligible, would lie somewhere between the adiabatic, with all condensation products retained, and that special type of the nonadiabatic which Neuhoff and others have called pseudoadiabatic, where all such products are immediately removed, probably much nearer the latter than the former.

To reduce adiabatic to "pseudoadiabatic" equations it evidently is only necessary to drop the water and ice terms. This of course, automatically excludes the hail stage—it eliminates all water and therefore renders freezing impossible. Nevertheless the differences between the temperatures and pressures given by the two processes generally are small.

For convenience of inter-comparison the two sets of equations, adiabatic and "pseudoadiabatic," are here grouped together.

$$\text{Dry stage}\begin{cases}\text{Adiabatic, } \log\frac{p}{p_o}=\frac{C_p+wC'_p}{A(R+wR')}\log\frac{T}{T_o}\\ \text{"Pseudoadiabatic," Does not exist, there having been no condensation.}\end{cases}$$

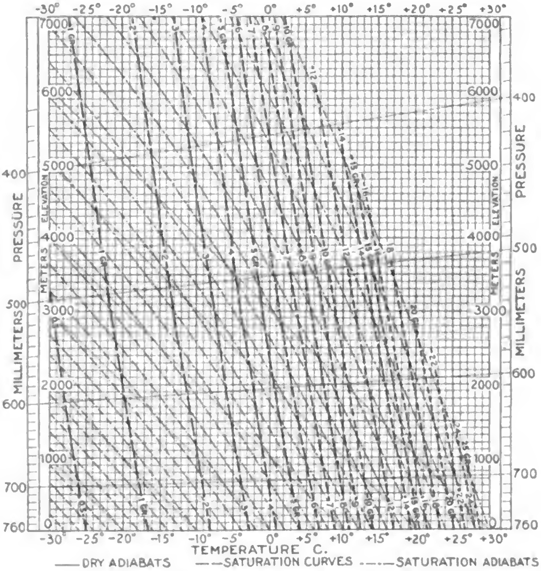
$$\text{Rain stage}\begin{cases}\text{Adiabatic, } \log\frac{p'}{p'_o}=\frac{Cp+ws_1}{AR}\log\frac{T}{T}+\frac{M}{AR'}\left(\frac{eL}{p'T}-\frac{e_oL_o}{p'_oT_o}\right)\\ \text{"Pseudoadiabatic," } \log\frac{p'}{p'_o}=\frac{C_p}{AR}\log\frac{T}{T_o}+\frac{M}{AR'}\left(\frac{eL}{p'T}-\frac{e_oL_o}{p'_oT_o}\right)\end{cases}$$

$$\text{Hail stage}\begin{cases}\text{Adiabatic, } \log\frac{p'_1}{p'_o}=\frac{M}{AR'T_1}\left(\frac{e}{p'_1}(L+F)-\frac{e}{p'_o}l-\frac{R'}{R}wF\right)\\ \text{"Pseudoadiabatic," Does not exist, there being no water and therefore no freezing.}\end{cases}$$

$$\text{Snow stage}\begin{cases}\text{Adiabatic, } \log\frac{p'}{p'_o}=\frac{C_p+wsi}{AR}\log\frac{T}{T_o}+\frac{M}{AR'}\left(\frac{e(L+F)}{p'T}-\frac{e_o(L_o+F_o}{p'_oT_o}\right)\\ \text{"Pseudoadiabatic," } \log\frac{p'}{p'_o}=\frac{C_p}{AR}\log\frac{T}{T_o}+\frac{M}{AR'}\left(\frac{e(L+F)}{p'T}-\frac{e_o(L_o+F_o)}{p'_oT_o}\right)\end{cases}$$

It will also be convenient to have listed the several constants of these equations and their numerical values. If the unit of heat

FIG. 60.



Adiabatic diagram (Neuhoff).

is 1 calory, the heat necessary to raise the temperature of 1 gramme of water from 0° C. to 1° C., the values of these constants are:

$A = \frac{1}{4.19} \times 10^7$ ergs, nearly.
$F = 80$ calories, about.
$L = 600$ calories, approximately.
$M = 0.43429448$, for base 10.
$T = 273 +$ reading of centigrade thermometer.
$R = 28.71 \times 10^5$ ergs per gramme 1° C., nearly.
$R' = 46.42 \times 10^5$ ergs per gramme 1° C., closely.
$C_p = 0.241$, about.
$C'_p = 0.46$, roughly.
$s_1 = 1$, closely.
$s_i = 0.5$, approximately.

With these values various tables may be constructed for convenient use of the formulæ, as has been done by Neuhoff.[80] Proper hypsometric formulæ give the elevations above sea level corresponding to different conditions of the atmosphere with respect to temperature, pressure, and humidity. Hence it is possible to construct diagrams more or less accurately embodying all such calculations. Fig. 60, copied from Neuhoff's paper, is an especially good adiabatic diagram of this kind.

As is obvious from inspection, this diagram applies to all altitudes from 0 (sea level) to 7000 metres, and from –30° C. to +30° C. The temperature and altitude differences are equally spaced, and the pressure differences, therefore, unequally in respect to both the other terms. It is assumed that the adiabatic cooling of non-saturated air is at the rate of 1° C. per 100 metres increase of elevation, an approximately correct value, hence the dry adiabats, given in full lines for intervals of 10° C., are straight diagonals, while the saturation adiabats, represented by dot and dash, are considerably curved. The saturation moisture content, in terms of grammes of water vapor per kilogramme of dry air, is given by the broken lines.

Interpolations are readily made on the diagram and approximate values easily obtained by always starting from the intersection of the given temperature and pressure coördinates. For example, let the temperature be 20° C., the barometer reading 760 mm., and the relative humidity 55 per cent. Since, as the diagram shows, saturation at the given temperature and pressure would require about 14.6 grammes of water vapor per 1000 grammes of dry air, it follows that under the assumed conditions only about 8 grammes would be present. Hence the temperature, pressure, and altitude of such a mass of air rising adiabatically are given, through the first convective stage, by that dry adiabat that starts at the intersection of the initial temperature and pressure ordinates, 20° C. and 760 mm. The first stage terminates when saturation is attained, and therefore, in the present case, at the intersection of the given adiabat with the 8-gramme humidity curve at an elevation, as inspection shows, of rather more than 1100 metres and where the pressure corresponds to a barometric reading of about 625 mm. From this level up the conditions of the rising mass of air are given by a saturation adiabat, according to which the temperature will have fallen to 0° C. and the humidity to about 5.25 grammes at an elevation of approximately 2700 metres. The humidity decrease, 2.75 grammes per 1000 grammes of dry air, is the amount precipitated as water in the form of cloud particles and rain drops. If all this water is carried along, its latent heat of fusion will maintain the temperature at 0° C. through an additional rise of about 80 metres, but, as much of this water obviously must drop out, it follows that the actual conditions presumably are rather better represented by omitting the "hail stage," or by a continuous rather than a broken adiabat.

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[80] *Loc. cit.*

While this diagram gives approximately the relations between temperature, pressure, humidity, and altitude that obtain in regions of strong vertical convection, it does not closely represent them as they normally exist at other places. This is due partly to the horizontal component of air movement, as above explained, and partly to that constant emission and absorption of radiation that always precludes the existence in the atmosphere of strictly adiabatic conditions.

Why the Atmosphere Generally is Unsaturated.—It may, perhaps, seem strange that, in spite of the continuous and rapid evaporation from nearly all parts of the earth's surface, the atmosphere as a whole never becomes even approximately saturated. This condition, however, is a necessary result of vertical convection. Obviously whatever the temperature and relative humidity of a given mass of air at any point of its convectional route, its absolute humidity is less then, in general, than when its ascent began, by the amount of rain or snow already abandoned by it. That is, on the average, air in a convection circuit descends to the earth dryer than when it previously ascended from it. In short, convection, because it induces abundant precipitation is therefore a most efficient drying process; and because comparatively little precipitation is produced in any other way, convection alone prevents the atmosphere from becoming and remaining intolerably humid.

Summer and Winter Precipitation.—Vertical convection, essential as above explained to all considerable condensation, results from three distinct causes: (*a*) superadiabatic temperature gradients, due often to surface heating; (*b*) converging winds, as in the front half of cyclones; and (*c*) forced rise from (1) flow over land elevations and barriers of cold air, (2) underrunning of cooler winds. The first or thunderstorm type of convection causes much of the summer precipitation of temperate regions, as also nearly all the rain of the tropics, while the second or cyclonic convection produces by far the greater part of winter precipitation, except, perhaps, that which occurs along the windward sides of the most favorably situated barriers. Also, during the colder season precipitation usually occurs lower down the barrier slope and may be induced by feebler cyclones or other storms than in the warmer. This is owing in part to the fact that generally there is less difference between the actual and dew-point temperatures during winter than during summer (a condition determined by the great seasonal temperature changes of continents with reference to the ocean), and therefore a less convection required in the first case than in the second to induce condensation, and partly to the greater rate of decrease of temperature with increase of latitude while the days are short than while they are long, a condition that favors winter precipitation by causing a greater fall of temperature during the winter season than any other for a given travel of the wind on the front or rainy side of a cyclone. That is, usually a less vertical convection and a less horizontal travel of the air—a feebler storm—suffices to induce precipitation during winter than during summer.

The contrasts, then, between summer and winter precipitation are manifold. A typical case may be illustrated by the following table:

Contrast Between Summer and Winter Precipitation.

	Summer	Winter
Rain	Usually.	Often.
Snow	Never.	Frequent.
Hail (ice lumps)	Occasionally.	Never.
Sleet (frozen rain)	Never.	Occasionally.
On barrier	High.	Low, and up.
Type of storm	Thunderstorm frequently	Cyclone.
Strength of convection	Strong, generally essential	Feebler, often sufficient.
Intensity of cyclone	Decided, usually essential	Slight, often sufficient.

(*To be continued.*)

A NEUTRAL-TINT AND VARIABLE-TINT SCREEN.*

BY

E. KARRER, Ph.D.,

Physicist, Research Depa tment, United Gas Improvement Company.
Member of the Institute.

VARIOUS devices have been described for controlling the intensity of a beam of radiation. In particular, most of these devices are intended to allow changes in the intensity of light by an infinite number of steps, according to some simple law which shall be the same for any and all wave-lengths; *i.e.*, the screen shall be neutral.

Most of such screens depend upon the absorption of light chiefly by opaque, solid bodies. Reflection is depended upon in certain few cases. The Nicol prisms and piles of glass plates belong to the former, together with those recently considered by Mr. E. F. Kingsbury [1] and with photographic wedges.

Scattering is depended upon in the screens which decrease the light proceeding in a certain direction by diffusing it, and is important in certain glass wedges and in photographic wedges. A photographic film, when mounted so that it may be turned, is an admirable neutral-tint screen for short limits.

Solutions have never been made for neutral-tint absorbing screens, though it may be feasible to use opaque particles in a liquid, allowing them to arrange themselves under gravity or some other force and thus obtain a graduated wedge. Colloidal solutions that will jell might be used in this connection.

The chief feature of disadvantage in most of the neutral-tint screens is the low maximum transmission, which cannot be increased, or, if at all, only by decreasing the range of the screen.

In most of the cases cited the maximum transmission cannot be more than 50 per cent.

Having occasion, in recent work, to employ neutral-tint screens for use in a compact photometer, I was disappointed with the low maximum transmission of those available.

The neutral-tint screen described here is intended to overcome this disadvantage somewhat. However, the universality of the present screen is probably its chief point of recommendation, for it can easily be made as a variable-tint screen for use in various experiments and practices where different tints of light are compared or matched.

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* Communicated by the Author.

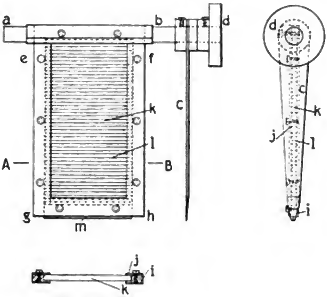
[1] JOURNAL OF THE FRANKLIN INSTITUTE, vol. 181, March, 1916, p. 369.

A very great convenience in a screen is to be able to see an object through it as the screen here described allows. Many screens do not afford this.

A brief description of the present screen is as follows, taken in connection with Fig. 1:

The screen proper consists of small, rectangular glass bars (*k*), cut from a plate of glass, whose cut edges are ground so as to be neatly laid together. Between the bars are laid some narrow strips of thin, opaque material (*l*); *e.g.*, black paper.

FIG. 1.



SECTION A-B

Showing the construction of the neutral- and variable-tint screen.

The glass bars are laid in a groove in a metal frame and held in place by a thin metal covering of the shape and size of the frame (*efgh*) and attached to it by means of screws. For rotating the screen an axis (*AB*) and a pointer (*C*) are provided.

The axis was placed at the end for adaptation to an existing mount where as long a pointer as possible was desirable without unnecessary lengthening of other parts.

d is a milled edge wheel by which to turn the screen.

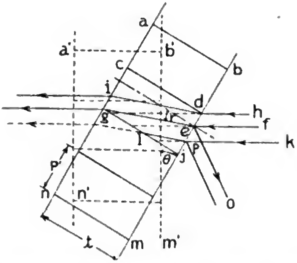
m is a metal plate with slots so that it may be moved inward to press the glass rods together.

An end view of a thin section taken out at *AB* is given to show the manner of holding the glass bars; *i* is the metal frame; *j* the clamping plate; *k* the glass bar.

In the right-hand picture is a view of the screen seen edgewise, where the symbols have been defined already.

When the screen is placed in a beam of light it will obstruct a portion of the light, depending upon the angle which it makes with the beam. The theory of it will be clear by reference to Fig. 2, where *abmn* is a longitudinal section of the screen. *cdgj* is the cross-section of a glass bar against whose sides are opaque films *cd* and *gj*.

FIG 2.



Showing the passage of light through the neutral-tint screen.

The thickness of the screen is designated by *t;* the spacing of the screen or width of glass bars by *s*.

The effective length of the bars in this screen is 3.16 cm.; *t* is 2.23 mm.; *s*, 1.42 mm.

If a beam of parallel rays of light 1 sq. cm. in cross-section is incident upon the screen, a maximum amount of it will be transmitted when the screen is in the position of *a'b'm'n'*. When it is inclined to the direction of the beam, a greater area of the opaque films will be presented to the beam and less of its energy will be transmitted.

Not only due to this absorption will the amount of energy transmitted become less as the screen is tilted, but also due to the reflection from the surfaces of the glass bars.

A ray of light *fe* incident upon the screen at an angle (θ) will be in part reflected (*eo*) and in part refracted and transmitted

(eg), while a ray kp will similarly be reflected and refracted, but absorbed by the opaque film gj.

If we let R be the per cent. of energy reflected by the glass surfaces, A that absorbed by the opaque films, S that scattered, and T the per cent. of energy transmitted, we may write $R + T + A + S = 1$. When the glass bars are clear, with smooth plane surfaces, and the films are opaque, there is no scattering and $S = 0$.

$$\text{So that } T = 1 - A - R \qquad (1)$$

Both A and R are functions of the angle.

The values of R may be calculated by the Fresnel formula for light reflected from the surface of a transparent medium whose refractive index is known.

$$R = 1/2 \left(\frac{\sin^2 (i-r)}{\sin^2 (i+r)} + \frac{\tan^2 (i-r)}{\tan^2 (i+r)} \right) \qquad (2)$$

where i and r are the angles of incidence and refraction respectively.

The value of A may readily be shown to be $\frac{t}{s}$ tan r where t and s have been defined above and r is the angle of refraction and is related to θ by $\sin r = 1/\mu \sin \theta$. μ is the refractive index of the glass.

The width of the transparent portions of the screen is $(s\text{-}cj)$, but $cj = t \tan r$.

The amount of light striking an opaque portion is proportional to the projected area $(t \tan r) \cos \theta$.

The number of such opaque portions struck by a beam of light of unit cross-section is $\frac{1}{s \cos \theta}$ if we neglect the thickness of the opaque film.

So that the amount of light absorbed is proportional to the product of these quantities, or $\frac{t}{s} \tan r$.

$$\text{Then } T = 1 - \frac{t}{s} \tan r - R \qquad (3)$$

In Fig. 3 is shown the effect of changing the ratio.

t/s, curve A, was obtained with a screen where $t/s = 1.03$, while curve B was obtained with the same screen after making the glass bars narrower, such that t/s is 1.57.

The effect of the refraction of the light by the glass is to extend the scale. Curve D, Fig. 3, shows the curve for $t/s = 1.57$

when the glass bars are removed. The index of refraction now is unity and $r = \theta$, so that formula 2 becomes

$$T = 1 - t/s \tan \theta \qquad (4)$$

For $R = 0$ also.

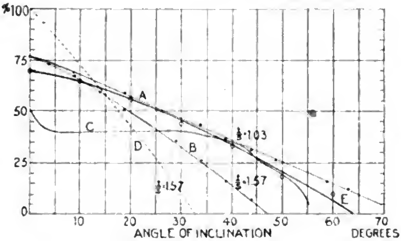
In Fig. 4 are shown separately the three factors of importance which affect the light passing through the screen.

The reflection has been calculated from equation (2), using 1.61 as the refractive index which was measured for one of the rods.

The absorption has been calculated, for $\mu = 1.61$ and $t/s = 1.57$

The transmission curve is obtained from the curve for reflection and absorption according to formula 3.

FIG. 3.



Correction has been made for the thickness of the films and is included in the curves for reflection and absorption.

There were certain other losses in the screen due to the fact that the edges were not sharply ground and due to the fact that during the process of grinding the surfaces of the bars were somewhat mutilated.

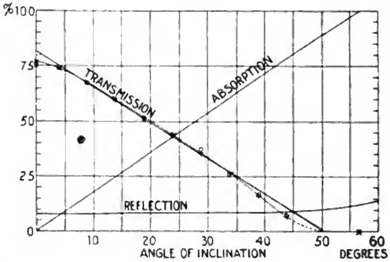
These losses probably account for the discrepancy between calculated and experimental values. The latter were uniformly 11.9 per cent. lower than the former. In the curves for the transmission in Fig. 4, the heavy line represents the calculated values after multiplying by 0.881. Several screens were made and their transmission factors obtained both for parallel rays and for diffused rays. The curve in thin line with the circles and crosses represents a typical case. The crosses are observations with parallel rays, the circles observations with well-diffused rays.

The differences are not great and are within the accuracy that was sought for the present determination.

The experimental curve departs from the theoretical curve at both extremities, being generally lower in each case. This is due probably in part to such imperfections already noted and to scattering and diffraction. Beyond 50 degrees, where the experimental values become higher, diffraction effects are probably present and scattering by the opaque films, some of which were slightly translucent, together with reflection by the black films at great angles of incidence. The black film in this screen was the ivory black of ordinary "water colors."

The amount transmitted at 56.75° is 0.004 per cent.

FIG. 4.



Having now described the general structure and characteristics of the screen and the manner of operating it, I shall point out a few modifications of it that may be important in heterochromatic photometry, in colorimetry, in illuminometry, and in pyrometry.

The characteristics may be altered by using bars whose cross-section is not rectangular. In Fig. 3, curve C is shown the transmission curve of a screen made of round rods of glass.

The round rods were ground flat where they lay in contact. The opaque film was black lacquer. The rods were not of uniform size and shape. The mean diameter of the rods was about 1 mm. The light transmitted by this screen was diffused, and objects could not be seen through it. The most characteristic feature of it is the quite constant transmission for wide angular movements. This may be of importance when we consider the next modification of it for use as a variable-tint screen.

If these rods were made of quartz, we should have a neutral-tint screen for the ultra-violet radiation.

If, instead of opaque absorbing films, we were to insert transparent and colored films, we would have a means of varying the color of the beam of light transmitted; for, as the screen is tilted, a greater portion of the beam is caused to pass through the colored films. A screen was constructed of rectangular bars with layers of a red gelatine film between them. The gelatine film transmitted chiefly in the red, but also to a very slight extent the blue.

There was no selection possible in using the red film, being one that is commercially used for theatrical effects; so that the results given below that were obtained with this screen are only roughly indicative of what may be accomplished by the use of the variable-tint screen when properly constructed.

The values of t and s for this screen are 0.113 cm. and 0.143 cm. respectively. The edges of the film were not very evenly laid with respect to the edges of the glass bars.

Curve E of Fig. 3 is the transmission curve for the red screen obtained by myself by direct comparison method of photometry. Its transmission is not very greatly different from the first screen described, where opaque films were employed—indicating high density of the red gelatine film.

When this screen was used, together with a layer of three plates of very light yellow glass, a very wide range of illuminants could be matched.

The transmission of the yellow glass was 53.1 per cent. for a tungsten point source lamp operated at normal voltage.

A tungsten filament lamp could easily be made to appear like the point source 4-watt lamp.

A point source tungsten 100 watts, operated at 120 volts, could easily be matched in an intensity of illumination given by the 4-watt carbon stereopticon lamp operated at 80 volts at a distance of 42.9 cm.

The variable-tint screen was inclined about 28.7 degrees. At this angle its transmission factor is 47 per cent., so that the total light transmitted by the color screen was 25 per cent., which is very low. However, no refinements were sought in these preliminary trials of the screen.

A Welsbach mantle could also be excellently matched in color with the same carbon lamps.

The use of the additional yellow screen with the variable-tint red screen on the side of the lamp, whose light was to be altered so as to match the carbon lamp, made it possible to have either the first or the second source appear either yellower or redder than the other.

In conclusion I wish to express my appreciation for the valuable criticism and suggestions given by Mr. E. F. Kingsbury in this work and for the encouragement given by Mr. C. O. Bond.

By means of two or three screens with a suitable source of light, wide ranges in tint may be matched.

Two screens have been constructed in which the colored medium was the dyed gelatine filters used in color projection. These red and green screens were the Wratten stained gelatine light filters, Series No. 60, Reference P, and Series No. 25, Reference A, respectively, which may be procured from the Eastman Kodak Company.

A variable-tint screen with much greater fineness of structure but with lower maximum transmission may be made by the use of photographic plates.

An ordinary negative is made having a sufficient number of opaque lines to give the desired fineness (say 20 to the inch). The lines are as wide as the clear spaces between them.

From this negative another may be made exactly its counterpart, where, however, the opaque lines are colored. This is brought about by the phenomenon known to color photographers of the hardening of gelatine when treated with a bichromate salt.

The gelatine on a plate so treated is rendered more or less insoluble when exposed to light, and after washing and drying may be stained by immersion in dyes.

Having these two plates—the one with spaces opaque, clear, the other with spaces colored, clear—one superimposes them in such a way that the opaque lines of the first register with the colored lines of the second. In this position they are suitably cemented.

When this screen is mounted as described above it will present a different tint, depending upon the angle of inclination.

These experiments were not completed when work in this direction was halted.

United Gas Improvement Company,
Physical Laboratory,
Philadelphia, Pa.,
October 26, 1917.

NOTES FROM THE U. S. BUREAU OF STANDARDS.*

METRIC PUBLICATIONS.

In view of the great demand for information on the metric system for use of our forces in France, and for the use of the War and Navy Departments in this country, as well as for manufacturers of war materials, the Bureau has been distributing, on request, copies of its publications on the International Metric System. These include a descriptive pamphlet, a graphic chart, a metric comparison scale, a circular giving definitions and tables of equivalents, a report of the metric system in the export trade, and a supplement to the table of equivalents giving the millimetre-inch equivalents. In view of the order recently issued by the Ordnance Department, adopting the system for use for specified purposes, the demand for the charts for instruction of officers, aviators, and others has been especially heavy.

WAVE-LENGTH MEASUREMENTS IN SPECTRA FROM 5600 TO 9600 Å.[1]

By W. F. Meggers.

[ABSTRACT.]

During the past thirty years the spectra of the chemical elements have been quite thoroughly investigated in the wave-length region to which ordinary photographic plates are most sensitive—that is, from 2000 Å to 6000 Å (Å = angstrom = 0.0000001 mm.) This was made possible by Professor Rowland's invention of the concave grating and the establishment of his system of standard wave-lengths. Since 1904 a new system of wave-length standards—the international system—has been established and the wave-lengths from 2000 Å to 6000 Å of many spectra have been re-measured in international angstroms.

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* Communicated by the Director.

[1] Scientific Paper No 312, Bureau of Standards.

The long waves have never been so extensively or carefully investigated, because of the great difficulty in photographing them. Measurements of the wave-lengths of some of the strong lines in the red and adjacent infra-red regions of the spectrum have been made by using radiometers or phosphoro-photography to detect the waves. These methods, however, are difficult and yield results which are not in very good agreement. It is generally conceded that nothing can compete with direct photography for the accurate determination of the structure and wave-lengths of spectral lines.

The photographic work on long wave-lengths has been done principally with ordinary photographic plates which have been specially treated with dyes to make them sensitive to these long waves. Such dyes as alizarin, nigrosin, cyanin, and dicyanin have been used for the purpose. Up to the present, however, comparatively few spectra have been investigated by this method. In most cases photography with stained plates has not registered waves much longer than 8000 Å, although it is possible to reach much longer waves by this method. Furthermore, such work has been done chiefly with the low dispersion of prisms or concave gratings with small radius of curvature, and very few long wave-lengths have been measured in international ångstroms. By using the photographic method with interferometers or with larger gratings, accurate information concerning the spectra of the elements can be extended to regions beyond 9000 Å without much difficulty.

Some work on spectroscopic analysis at the Bureau of Standards led to a photographic investigation of the spectra of some of the elements in the region of longer wave-lengths. The photographic sensitizers dicyanin and dicyanin A were used and found to be of great value in photographing spectra between the wave-length limits 5600 Å to 9600 Å. This work was begun with the plan of studying the longer waves of the spectra of elements commonly found in iron as impurities, such as nickel, cobalt, chromium, manganese, copper, titanium, vanadium, silicon, calcium, and carbon. The success in photographing these led to the photography of the spectra of the following elements in addition to those mentioned: lithium, sodium, potassium, rubidium, cæsium, beryllium, strontium, barium, and magnesium. Thus the arc spectra of twenty of the chemical elements were photographed from 5600 Å to 9000 Å or beyond.

Accurate measurements of wave-lengths to 8824 Å in the arc spectrum of iron have been made with interferometers by Burns. Similar measurements have been made to 8210 Å in the barium-arc spectrum by Werner. These spectra do not contain a sufficient number of evenly distributed and sharp lines in this region to recommend them as entirely satisfactory for standards. A photographic survey of the spectra of the elements may disclose a more satisfactory source for long-wave standards.

Some of the spectra which were photographed, notably those of cobalt, nickel, titanium, vanadium, manganese, and chromium, were found to have sharp lines whose wave-lengths can be more accurately obtained with interferometers than from the grating photographs made in this work. Furthermore, the number, distribution, and intensity of lines in this part of the cobalt-arc spectrum were found to be more satisfactory than in the iron-arc spectrum.

If the sharpness of these cobalt lines be examined with the interferometer, the cobalt arc may be found superior to the iron arc as a source of long-wave standards. The wave-length measurements in these sharp-line spectra will therefore be postponed until the interferometer is applied.

Many elements, especially the alkali metals, have spectra the greater part of whose lines are broad, diffuse, reversed, or unsymmetrical. A careful study of the long-wave spectra of some of these elements has been made.

The wave-lengths have been measured in international ångstrom units, and the results are probably as accurate as the structure of the lines will permit. These results are of special interest because of the regularities and series relationships which exist in the spectra of the II and III groups of elements in the periodic system. The apparatus and method used in photographing and measuring these spectra are described in this paper, and the results are given for lithium, sodium, potassium, rubidium, cæsium, copper, beryllium, calcium, strontium, barium, and magnesium.

THE PROPERTIES OF PORTLAND CEMENT HAVING A HIGH MAGNESIA CONTENT.[2]

By P. H. Bates

[ABSTRACT.]

A SERIES of cements was burned in the Bureau's experimental rotary kiln in which the limestone used in the raw material was replaced in part or in whole by dolomite. A magnesia content as high as 25 per cent. was obtained in the resulting cement, and the clinker was examined petrographically. The constituents present, their amount, and the character of their formation were carefully studied. The clinker was also ground and the resulting cement subjected to the usual tests for physical properties. The results show that cements not exceeding 8 per cent. in magnesia content will produce concretes of satisfactory strength at the end of 1½ years. With this amount of magnesia, monticellite and spinel (constituents not present in cements of lower magnesia content) appear; and these cements seem to hydrate with a large increase in volume.

COMBINED TABLE OF SIZES IN THE PRINCIPAL WIRE GAUGES.[3]

By R. Y. Ferner.

THIS table combines in one series the sizes in the American (B. & S.), Steel, Birmingham (Stubs'), British Standard, and Metric Wire Gauges, arranged in order of sizes (diameters) of wires. It gives the diameters of all the gauge numbers in these five systems in mils, millimetres, and inches, also the cross-sections in square mils, circular mils, square millimetres, and square inches. The table is specially useful to manufacturers who wish to determine the nearest equivalent in American or British gauge sizes of wires specified in millimetres or square millimetres, or *vice versa*.

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[2] Technologic Paper No. 102, Bureau of Standards.

[3] Circular No. 67, Bureau of Standards.

NOTES FROM NELA RESEARCH LABORATORY.*

THE MEASUREMENT OF TRANSMISSION FACTOR.

By **M. Luckiesh** and **L. L. Mellor.**

In a previous paper [1] one of the authors discussed the conditions which affect the value of the reflection-factor of a surface not perfectly diffusing, and pointed out the difficulties in making such measurements. It was concluded that the measurement of reflection-factor should be determined in general for highly diffused light. A similar investigation has been prosecuted with the purpose of studying the measurement of transmission-factors of ordinary glasses of the partially diffusing type, such as sand-blasted, etched, ribbed, and pebbled glasses. In both investigations it was aimed to devise a simple apparatus for determining these values by measuring a single quantity after the apparatus is duly calibrated. For the measurement of transmission-factor the integrating sphere was an essential part of the apparatus. The transmission-factors were determined both for (1) a narrow pencil of light directed perpendicularly to the glass specimen and (2) hemispherical illumination or highly diffused light. In general, as was to be expected, the transmission-factor was less for diffuse illumination than for the perpendicular pencil of light. Furthermore, in the case of the narrow pencil of light, the transmission-factors of these glasses were less when the smooth side faced the light-source than when the rough side faced the light-source. This difference is very apparent for certain ribbed glasses, being as much as 50 per cent. It amounted to about 5 per cent. for the sand-blasted and etched glasses. The difference is readily accounted for in the case of a crystal glass with one rough surface by assuming that, when the smooth side faces the light-source, the rough side reflects a certain amount of light owing to the similarity of many of the rough points to reflecting prisms. This would only obtain at the glass-air surfaces and not at the air-glass surfaces in case the specimen were reversed. In most cases the transmission-factors were between 0.70 and 0.85.

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* Communicated by the Director.

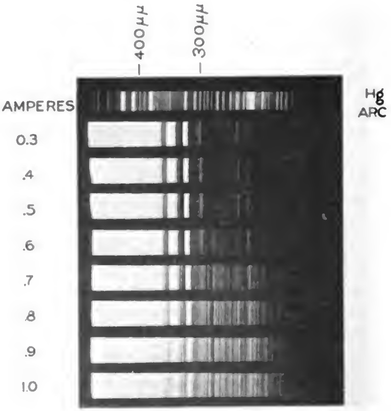
[1] *Electrical World*, 69, p. 958 (1917).

A number of simple photographic procedures have been devised for illustrating the physical and optical characteristics of specimens of glass of this type.

THE ULTRA-VIOLET SPECTRUM OF THE TUNGSTEN ARC.

By M. Luckiesh.

ALTHOUGH much desired, there is not available a light-source emitting a continuous spectrum between 200 and 400$\mu\mu$. The quartz mercury arc emits many lines in this region, but the spectrum does not approximate continuity. Some arcs (particularly flame arcs) and electric sparks provide ultra-violet spectra which find many uses, but these are not usually steady sources. The ultra-violet spectrum of tungsten is very rich in lines in this region, and, inasmuch as a tungsten arc can be made to operate quite steadily in certain gases, its spectrum was studied with the aim of determining the adaptability of such an arc to various problems.



A glass bulb was provided with a plane quartz window opposite the tungsten electrodes. Commercial argon, containing about 20 per cent. nitrogen, was admitted to the evacuated bulb at a pressure of 20 cm. of mercury. Spectrograms were made for currents varying from 0.3 ampère to 5.0 ampère. For this particular arc the ultra-violet energy between 200 and 300$\mu\mu$ is relatively weak for the lowest currents at which the arc operates. The energy in this region apparently increases more rapidly than the near ultra-violet energy as the current is increased until about one ampère is reached. In the illustration the spectrograms are shown for currents up to one ampère, the exposure being constant for the entire group. The spectrum between 300 and 400$\mu\mu$ may be considered approximately continuous for some purposes, although shorter exposures show that it is somewhat fluted in character.

The arc voltage varied from 28 to 16 volts as the current increased from 0.3 to 5.0 ampères respectively, thus consuming from 5 to 80 watts. This arc was quite steady and is adaptable to many physical and chemical problems. It may be made much more powerful to suit requirements.

A Thermo-electric Standard Cell. C. A. HOXIE. (*Proceedings of the American Institute of Electrical Engineers*, vol. 37, No. 2, p. 57, February, 1918.)—Most engineers are familiar with the uses and limitations of standard cells of the Clark or Weston types. Neither of these cells will function at freezing- or boiling-point temperatures, and both are easily damaged if an appreciable current is drawn, as by accidental short circuit. Though the thermo-electric cell is not, strictly speaking, a primary standard or source of electromotive force, as the Clark or Weston cell, it is at least free from these drawbacks. It may be more properly classed as a secondary standard, its value being determined by comparison with a primary standard.

The cell consists essentially of a circuit comprising a drop resistance, across which the standard electromotive force is obtained, a heating filament, and a balancing resistance across which the electromotive force of a thermocouple adjacent to the heating filament is balanced. The potential across the balancing resistance is a linear function of the current, while that of the thermocouple varies approximately according to the second power of the current. Balance is therefore obtained for some fixed value of current which determines the standard electromotive force across the drop resistance. Means are provided for compensating for the temperature coefficient of the cell. The standard cell has been successfully applied to potentiometers designed for thermocouple work.

Canvas Tubing for Mine Ventilation. L. D. FRINK. (*Mining and Scientific Press*, vol. 116, No. 7, p. 223, February 16, 1918.)—Metal tubing with blower or exhaust fans has long been used for supplying air to dead ends where natural ventilation is impossible. In Butte, canvas tubing is now used extensively because it is found that it has many advantages not possessed by the metal. Although the use of flexible tubing is not new, it has not been generally used in mining operations. Recent improvements, however, in the canvas itself, in the joining of sections, and in the manner of suspension have so increased its usefulness that it promises to add much to the efficiency of mining. A product is now on the market that is impervious to air and fireproof, and provided with a system of jointing that permits it to be put up or taken down in a few seconds.

Connections were first made by slipping the ends of adjacent sections over a 6-inch metal hoop and holding the canvas in place by wiring. Later a more efficient and secure joint was made by sewing-in at the ends of each section a flexible contracting ring. These rings are alike, and the joint is made by contracting one ring and forcing it past that of the adjacent section. When released it assumes its normal diameter and cannot be withdrawn past the neighboring ring. In the hem of the tubing, at intervals of three or four feet, grommets or eyes are inserted, and in these are fastened wire clips or hangers. By means of these hangers the tubing can be hung rapidly to a messenger or suspension wire. Each section is provided at the ends with grommet eyes closed with corks for the removal of water of condensation.

Airplane Dopes. G. J. ESSELEN, JR. (*The Journal of Industrial and Engineering Chemistry*, vol. 10, No. 2, p. 135, February, 1918.)—" Dope " is the term applied to the varnishes used on the wings of airplanes to render the fabric taut and waterproof. An airplane wing is made by covering a framework of the proper size and shape with a linen or cotton fabric. There are then applied to the fabric several coats of a suitable varnish, of which the base is either cellulose acetate or cellulose nitrate. The term " dope " seems to have arisen in the slang of the factory workman, but is now firmly fixed and is used to distinguish the cellulose acetate or nitrate " dopes " from the spar varnishes made up of gums and oils, which are sometimes used as a finishing coat. The chief function of the dope is to tighten up the fabric and give a smooth, taut, waterproof surface, resistant to the weather, and preferably also to oil and gasoline. It also adds to the tensile strength, the percentage increase depending somewhat upon the strength and character of the fabric and upon how much the fabric was stretched before doping. In Europe only acetate dopes are used, and it appears to be only a matter of time when the users of airplanes in this country will demand that every possible factor of safety be taken advantage of, which will mean the use of a non-inflammable dope.

NOTES FROM THE PHYSICAL LABORATORY OF THE UNITED GAS IMPROVEMENT COMPANY.*

A MODIFIED GAEDE GAUGE.

By Enoch Karrer.

THIS is an improvement in the gauge described previously by the author.[1]

In the gauge previously described all rubber parts of the short Gaede gauge were eliminated by the use of a ground-glass joint.

The present improvement consists in eliminating the ground-glass joint. The mercury reservoir is a steel cylinder, connected to the compression chamber by means of a small steel tube. This small steel tube has a helix which allows of mechanical freedom sufficient so that the mercury reservoir may be raised and lowered the desired height.

The compression chamber, with its calibrated capillary tube, is made of glass as before. The connection between the glass and steel parts may be accomplished by using hard wax, by a platinum cylinder connection, or by soldering.

This manner of using a mercury reservoir is suggested for other apparatus where either adjustable volume or pressure is required.

Development of the Steel Car. H. P. HOFFSTOT. (*Railway Age*, vol. 64, No. 9, p. 461, March 1, 1918.)—The change from the use of wood to steel in the construction of coal cars in America was extremely gradual in its development, although many years ago a few all-steel cars were built and placed in operation by some of the steel companies. In the early nineties C. T. Schoen commenced making pressed-steel car shapes in his little plant in lower Allegheny, and for years supplied the railroads with pressed-steel centre plates, side bearings, stake pockets, push-pole pockets, etc., for use in connection with the construction of wooden cars. During the same time The Fox Plant in the same locality was furnishing pressed-steel trucks and truck specialties to railroads for use on wooden equipment.

About 1895 Mr. Schoen conceived the idea of building steel cars on a large scale. The following year the first steel cars were ordered by the Pittsburgh, Bessemer and Lake Erie Line, and shortly after by the Pittsburgh and Western and the Pittsburgh and Lake Erie.

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* Communicated by the Manager.

[1] *Physical Review*, vol. vi (1915), p. 51.

It is therefore to the foresight and initiative of the officers of these companies that a great measure of the credit for bringing about the change from the wooden to the all-steel car must be given. The demand for this type of car grew rapidly, and the new construction virtually revolutionized railroad traffic in this country.

The first hopper cars were built to carry coal, and, while stencilled "50 tons," were hardly of 40 tons capacity, so far as present M. C. B. requirements are concerned. Probably 85 to 90 per cent. of these cars are still running after 20 years of service. Railroads are continually demanding cars of heavier capacity so that the increasing volume of freight can be more economically handled. The 70-ton car has come into general use, and several thousand 90-ton cars are in operation on at least one well-known railroad, which is also experimenting with a 100-ton car. Many 100-ton coal cars are now in operation on short lines about steel mills, and one road has now under test four cars of 120 tons capacity.

An Improved System for Lighting Interurban Trolley Cars. W. J. WALKER. (*General Electric Review*, vol. 21, No. 2, p. 124, February, 1918.)—The annoying variations in the intensity of lighting of interurban trolley cars resulting from variations in the trolley voltage is a familiar defect of the lighting equipment usually employed in this service. Apart from the discomfort produced by variations of the interior illumination of the car, with the high speeds prevailing on interurban railways, it is essential for safety to maintain a satisfactory headlight. The incandescent headlight would easily meet service requirements were it not for the trolley voltage variation, and there is obviously need of some device for controlling the voltage of the lighting circuits.

The General Electric Company has developed and recently placed on the market a motor-generator set that is peculiarly suited to railway car lighting, in that the generator provides a practically constant voltage over wide variations in speed. On a typical third-rail installation very dense traffic movements cause wide voltage variations, with inadequate car illumination and poor headlight protection. The third-rail gaps are a further source of annoyance, causing repeated blinking of the interior lights and interference with the headlight. Under these conditions the voltage ranges from 625 to 150 volts, or from glaring brilliancy to near-darkness with the usual series equipment, while the motor-generator set is maintaining practically constant interior illumination down to 350 volts and a readable interior as low as 200 volts. At 150 volts the headlight is projecting 700 feet, and from 350 to 650 volts a distance of 1300 feet. With the series system, the light is out at 150 volts and the projection between 350 and 650 volts varies from 350 to 1000 feet. In other words, the low-voltage equipment is furnishing at 350 volts at the trolley as good interior illumination and a considerably better headlight than the series system furnishes at any voltage.

NOTES FROM THE RESEARCH LABORATORY. EASTMAN KODAK COMPANY.*

THE SENSITOMETRY OF RÖNTGENOGRAPHIC MATERIALS.[1]

By Millard B. Hodgson.

[ABSTRACT.]

THE measurement of the sensitiveness of materials used in ordinary light-photography has already been reduced to a more or less exact science. In the system of photographic sensitometry developed by Hurter and Driffield, the important photographic constants may be expressed numerically with but little difficulty. It has been realized by investigators in Röntgen materials that the following factors could be investigated precisely and mathematically:

(*a*) Sensitiveness or speed.
(*b*) Contrast.
(*c*) Relation between sensitiveness, contrast, and wave-length of X-rays.
(*d*) Development characteristics.
(*e*) Fluorescent screen efficiency.

The chief obstacle to making accurate sensitometer exposures to X-rays lies in the difficulty of making consecutive exposures accurately. In white light and sensitometry, a simple rotating opaque sectored disk, with the openings proportional to the progression of exposures, may be interposed between the light-source and the plate and a series of exposures obtained simply and accurately. With the available Röntgen equipment such procedure is impossible. The current furnished to operate the tube efficiently is pulsating, with the maximum frequency usually 60 cycles per second. Therefore, by interposing the rotating sectored disk in front of the tube operated by such pulsating current more or less synchronism occurs and grave errors follow. The most feasible method of working is by moving the plate itself by intermittent motion across the path of the Röntgen-ray beam in such manner that a known progression of exposures is given, controlled to the desired accuracy.

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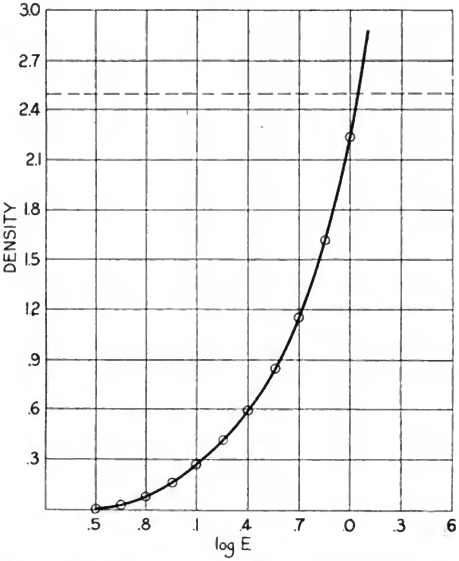
* Communicated by the Director.

[1] Communication No. 63 from the Research Laboratory of the Eastman Kodak Company, published in *American Journal of Röntgenology*, 1917, p. 610.

In the sensitometer adopted for the present work, the photographic plate is moved in this manner, the length of the exposure steps being controlled by an actuating electromagnetic mechanism.

For the study of Röntgen emulsions it was found most convenient to use an exposure progression of consecutive powers of the square root of two. The Röntgen-tube circuit was connected to a solenoid switch, this switch being operated at the proper time by the sensitometer mechanism. The entire operation of exposure was thus governed to within an error of three per cent.

FIG. 1.



In plotting the density values of the resultant exposure strips, no absolute values are assigned to the points along the abscissæ, the curve being located merely by the known progression of exposures given assuming an arbitrary exposure unit. Fig. 1 shows such a characteristic curve of the plate (Seed X-ray), obtained under the following conditions:

Tube—Medium focus Coolidge, 3-inch diaphragm stop.

Voltage—Ca 50,000.

Development — Five minutes at 70°, Elon-Hydrochinon formula.

It will be noticed that the type of curve is somewhat different from that usually obtained from white light exposure. The maximum density is beyond any which is optically measurable, even with the most intense light-source, the curve sweeping in a close approximation to a parabola, until a density of 5.0 or more is reached.

For average röntgenographic research, however, the portion of the curve to be considered is only that limited by such a density as can be seen through the average viewing frame. This is a density of about 2.5.

The method has been applied for the study of variation in the photographic effect of varying hardnesses or wave-lengths of X-rays. With the present types of X-ray emulsions the characteristic density exposure curve has been found to increase in slope or contrast with the softness of the tube; that is, with an increase in wave-length. The rendering power of the plate from these latter curves has been found to depend both upon the plate itself and the tube hardness. The method presents an accurate means for the measurement of intensifying screen efficiency.

Application of Concrete to Shipbuilding. ANON. (Monograph issued by Portland Cement Association, December, 1917.)—The pressing need for ships and the existing congestion in American shipyards have led to a consideration of the possibility of utilizing other materials than wood and steel for shipbuilding. Reinforced concrete is a most promising alternative, and its application to the construction of ships has of late received much attention. Although the possibilities of reinforced concrete as applied to shipbuilding are not widely known as is its use in building construction, at the present time nearly every country in the world is making some use of reinforced concrete in that field.

To what extent the development of concrete shipbuilding has taken place may be gathered from the operations of the San Francisco Shipbuilding Company, incorporated to undertake the construction of sea-going vessels of concrete. This company is now building an ocean-going cargo vessel of nearly 5000 tons, that will be about 330 feet long, with a beam of 46 feet. In constructing this vessel the reinforcement was welded together, thus reducing to a minimum the quantity of steel required by avoiding the lap that otherwise would have been necessary. Plans for this work were developed by Allan McDonald, of McDonald & Kahn, San Francisco. The original drawings indicated that the reinforcement used weighs less than the bolts needed in a wooden ship of equal dimensions, and that the hull will weigh less than that of a wooden ship. The motive power will be supplied by a 2500-horsepower turbine equipped with reduction gears.

Initial Current Obtained in Incandescent Lamps. C. J. BERRY. (*Electrical World*, vol. 71, No. 9, p. 459, March 2, 1918.)—The resistance of the filament of a tungsten lamp is many times greater when the lamp is lighted than when the lamp is not connected in the circuit. The ratio of hot to cold resistance is, approximately, for a vacuum-type tungsten filament, 11.5 to 1, and for a gas-lamp tungsten filament, 14.6 to 1, while for an untreated carbon filament the ratio is 0.5 to 1. When tungsten-filament lamps are first thrown in circuit, there is an initial rush or "overshooting" of current caused by the filament resistance of the cold lamp being low as compared to the resistance it has when the lamp is lighted.

The initial current under constant voltage conditions at the lamp is not as many times greater than the normal current as the ratio of hot to cold resistance. Line resistance and reactance drops, and also the behavior of the electrical apparatus supplying the energy, are factors which decrease the effective voltage at the lamp, thereby keeping the current from rising to a high degree. The higher-wattage lamps do not overshoot to so high a percentage above normal value as the lower-wattage lamps. The maximum current value is reached in a very short interval of time, varying from 0.0004 to 0.003 second. The current, after reaching its maximum value, immediately starts to resume its normal operating value, and this is reached in about 0.1 to 0.2 second, depending upon the size of the lamp.

With an alternating current, there is a marked distortion of the current wave form due to the alternating and cooling of the filament. The initial current rises to different percentages, depending upon the point of the voltage wave at which the lamp is thrown in circuit and also upon the condition of the magnetism of the transformer before the switch is closed. The overshooting occurring with vacuum-type lamps is slightly less than that taking place with gas-filled lamps, since the filament temperature of the gas-filled lamp is higher than the operating filament temperature of vacuum lamps. The blowing of fuses or the opening of circuit breakers can be avoided when the protective apparatus is of proper rating and set correctly, and has a small time-factor element.

NOTES FROM THE U. S. BUREAU OF CHEMISTRY.*

THE APPLICATION OF OPTICAL METHODS OF IDENTIFICATION TO ALKALOIDS AND OTHER ORGANIC COMPOUNDS.

By **Edgar T. Wherry.**

[ABSTRACT.]

OPTICAL-CRYSTALLOGRAPHIC methods of identification have been used heretofore chiefly in connection with minerals, although their applicability to synthetic substances has been pointed out by several recent writers. Dr. F. E. Wright, in particular, has made preliminary examinations of several alkaloids, and shown the probable value of this method. The present writer is working out this method in detail, and applying it to the varied problems of the food and drug analyst. The paper abstracted deals especially with the methods of work which have been found appropriate in connection with alkaloids and related substances.

A simple chemical or petrographic microscope, provided with revolving stage, Nicol prisms, Abbé condenser, sub-stage diaphragm, selenite plate, etc., is used. The observations made are as follows: in ordinary light, color, crystal habit, angles, cleavage, and refractive indices are observed. For the determination of the indices the immersion method is used, and, as the alkaloids in general are soluble in the immersion liquids ordinarily applied to minerals, special liquids are required. It has been found that solutions of potassium-mercuric iodide in diluted glycerine are satisfactory for many substances. The determinations are made by diminishing the light by the sub-stage diaphragm and bringing a grain lying in a definite crystallographic position into focus; then, on raising the microscope tube slightly, a band of light will pass into that substance, crystal or liquid, having the higher index in that direction. Successive liquids are tried until no light moves in either direction, when the index of the grain is equal to that of the liquid, which is known.

By inserting the crossed Nicol prisms observations may be made in parallel polarized light, comprising the extinction angle, strength of double refraction, and sign of elongation. By using, in addition, a high-power objective, inserting the condenser and removing the eyepiece, the interference phenomena in convergent polarized light are obtained. From the character of the figures it may be determined whether the substance is uniaxial or biaxial, whether its sign is positive or negative, and to what extent it exhibits dispersion.

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* Communicated by the Chief of the Bureau.

Before measuring these optical properties the substances must be purified, and the effect of the solvent from which they are crystallized must be considered, for solvent-of-crystallization is frequently taken up, modifying the crystallographic properties considerably. When working with very minute amounts of alkaloids it is convenient to extract them with benzene. The solutions are allowed to stand until reduced to small bulk. Large drops are then placed on several microscope slides and covered at once with small cover-glasses. Evaporation then takes place and the alkaloid crystallizes out round the edge of the cover. After the solvent is completely gone the immersion liquids may be introduced and the usual observations made. The data obtained in this way with the four cinchona alkaloids are to be published in a separate paper.[1]

THE IDENTIFICATION OF THE CINCHONA ALKALOIDS BY OPTICAL-CRYSTALLOGRAPHIC MEASUREMENTS.[2]

By Edgar T. Wherry and Elias Yanovsky.

[ABSTRACT.]

THE probable value of optical-crystallographic measurements for the identification of alkaloids difficult to distinguish by chemical means being evident, the cinchona alkaloids—cinchonine, cinchonidine, quinine, and quinidine—have been exhaustively studied from this point of view. Samples were purchased on the open market and purified and identified chemically by the junior author, the optical properties being then measured by the senior author.

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[1] To be published as a Professional Paper by the United States Department of Agriculture.

[2] Read at the November, 1917, meeting of the Association of Official Agricultural Chemists. To be offered for publication in the *Journal of the American Chemical Society*.

For determining the refractive indices by the immersion method, solutions of potassium-mercuric iodide in 50 per cent. glycerine were used.

The four alkaloids were found to be quite distinct in properties, and to be readily distinguishable. For instance, if crystallized from benzene and immersed in a liquid with refractive index 1.670, quinine is recognized at once by crystallizing in needles, all the refractive indices of which are much lower than that of the liquid, and which show between crossed nicols only first-order polarization colors, indicating the double refraction to be very low. Cinchonidine is in rods or plates, with the refractive index lengthwise somewhat less than that of the liquid, showing between crossed nicols mostly second-order colors, and yielding no interference figures in convergent light. Both cinchonine and quinidine have indices lengthwise higher than the liquid, but they may be recognized by immersion of another sample in liquid with index 1.690. Cinchonine shows the index lengthwise equal to that of this liquid; and yields an interference figure with a small axial angle. Quinidine has the index lengthwise equal to, or slightly lower than, the liquid, but its axial angle is large.

Experiments with mixtures and with drugs containing these alkaloids have shown these methods to be of considerable practical value, and application to other groups of substances is planned.

ARSENIC IN SULPHURED FOOD PRODUCTS.

By W. D. Collins.

[ABSTRACT.]

SMALL amounts of arsenic, from one to four parts of arsenic (As_2O_3) per million parts of product, have been found in hops and dried fruits treated with fumes from sulphur which contained arsenic. A number of samples of Japanese sulphur contained from 100 to 500 milligrammes of arsenic (As_2O_3) per kilogramme. It is generally known that sulphur from the largest source of supply in the United States is free from arsenic. A sample from this source, and samples from five other sources in the United States, all proved to be free from arsenic, or to contain less than one milligramme per kilogramme. Producers can avoid contamination of food products with arsenic from sulphur by burning, for curing the products, only sulphur known to be free from arsenic. If the sulphur cannot be tested, the use of that produced in this country will be an almost certain insurance of freedom from arsenic.

An account of the work, with full details of the analytical methods used, will appear soon in the *Journal of Industrial and Engineering Chemistry*.

THE DETERMINATION OF ARSENIC IN INSECTICIDES BY POTASSIUM IODATE.[3]

By George S. Jamieson.

THE method is based upon the titration of a hydrochloric acid solution of the arsenite with a standard solution of potassium iodate, using a chloroform indicator. The reaction between the arsenic and potassium iodate is represented by the following equation:

$$As_2O_3 + KIO_3 + 2HCl = As_2O_5 + ICl + KCl + H_2O.$$

It was found that there should be at least 11 per cent. of hydrochloric acid present at the end of the titration to prevent the hydrolysis of the iodine monochloride. Cupric and ferric compounds do not interfere with the titration. In the direct titration of insecticides, cuprous and antimonious compounds are oxidized by potassium iodate, as is the case with the iodine titration, but fortunately these compounds occur only in small amounts.

In order to apply this method to the determination of the total arsenic the official distillation process of the Association of Official Agricultural Chemists was employed to obtain all of the arsenic in the arsenious condition. The distillate was diluted to 500 c.c. and aliquots of 100 c.c. were titrated with potassium iodate without the further addition of hydrochloric acid unless more than 25 or 26 c.c. of the standard solution were required.

The investigation showed that arsenic could be satisfactorily determined by this method. Furthermore, the very definite and remarkably sharp end point, the great stability of the potassium iodate solution, and the readiness with which it can be prepared, recommend the method in preference to the iodine titration.

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[3] *J. Ind. and Eng. Chem.*, March, 1918.

THE FRANKLIN INSTITUTE.

(Proceedings of the Stated Meeting held Wednesday, March 20, 1918.)

HALL OF THE FRANKLIN INSTITUTE,
PHILADELPHIA, March 20, 1918.

PRESIDENT DR. WALTON CLARK *in the Chair.*

Additions to membership since last report, 6.

Reports of progress were presented by the Committee on Science and the Arts and the Committee on Library.

The President announced that the next business of the meeting would be the presentation of the Edward Longstreth Medal of Merit to Mr. Levi Talbot Edwards, and recognized Dr. H. Jermain Creighton, chairman of the Committee on Science and the Arts. Doctor Creighton made a brief statement in reference to the invention of the Air-Lift and its uses, and introduced the inventor, Mr. Edwards, who had been recommended by the Committee on Science and the Arts for the award of the Edward Longstreth Medal of Merit for his device. The President then presented the medal and accompanying certificate to Mr. Edwards, who thanked the Institute for the recognition bestowed upon him.

Mr. F. W. Sperr, Jr., Chief Chemist, The H. Koppers Company, Pittsburgh, Pa., then presented the paper of the evening, entitled "Characteristics of American Coals in By-products Coking Practice." The speaker called attention to the rapid replacement of the old beehive coke oven by the modern by-product oven, and some of the interesting economic developments in the coal industry which result from this change. The behavior of various American coals in the by-product oven was described in detail, and results of studies in this connection were presented. The coking property of coal and some of the important phenomena of the coking process were discussed. Attention was also given to the behavior of various typical coking coals in the by-product ovens, as well as the practical results of coking such coals, with respect to the yields of the various by-products, and the quality of the coke produced. The subject was illustrated by lantern slides and specimens.

After a brief discussion, the thanks of the meeting were extended to the speaker.

Adjourned.

GEORGE A. HOADLEY,
Acting Secretary.

MEMBERS OF THE FRANKLIN INSTITUTE WHO ARE IN THE ACTIVE MILITARY OR NAVAL SERVICE OF THE UNITED STATES GOVERNMENT.

Name and rank	Branch of service	Location
Allen, Henry B., 1st Lieut.	Ordnance Dept., U. S. R.	France
Anderson, Geo. L., Colonel	Board of Ordnance & Fortification	Washington
Atherholt, Gordon Meade	Aeronautical Mechanical Engineer, Signal Corps	Washington
Atterbury, W. W., Brig. Gen.	Director-General of Railways	France
Bacon, Raymond Foss, Lt. Col.	Head of Chemical Service Section, U.S.N.A.	France
Barnhart, G. Edw.	Aeronautical Mechanical Engineer, Signal Corps	Fairfield, Ohio
Barr, John H., Major	Ordnance Reserve Corps	Washington
Barrett, C. D., Major	9th Engineers	
Bartow, Edward, Major	U.S.N.A. Sanitary Corps	France
Booz, Horace Corey, Colonel	Railroad Transportation Corps, U.S.N.A.	France
Bostwick, John Vaughan, Capt.	O.R.C., 315th Infantry	Camp Meade
Breed, George, Lieutenant	Fleet Naval Reserve, U.S.N. R.F.	New York
Bunting, C. M., Colonel	E.O.R.C., U.S.A.	France
Cadwalader, Governeur, Major	Ordnance Dept., U.S.R.	
Caldwell, E. W.	Medical Officers' Reserve Corps	
Capps, W. L., Rear Admiral	Chief Constructor, U.S.N., Bureau of Construction and Repair	Washington
Carty, John J., Colonel	Signal Corps, U.S.A.	
Chance, Edwin M., Capt.	Ordnance Dept., U.S.R.	Washington
Clark, Beauvais, Sergeant	108th Field Artillery	Camp Hancock
Clark, E. L., 1st Lieut.	Signal Corps, 401st Telegraph Battalion	Camp Devens
Clark, Theobald F., Capt.	Field Artillery	Fort Sill
Clark, Walton, Jr., Capt.	Field Artillery	Fort Sill
Cornelius, John C., 1st Lieut.	Coast Artillery, U.S.N.A., 13th Company	Sandy Hook
Cottrell, Jas. W., Private	Instruction Section, Ordnance Dept., U.S.A.	Peoria, Ill.
Cowan, Henry B., Sergeant, 1st Class	Co. D., First Telegraph Battalion, Signal Reserve Corps	France
Crampton, George S., Major	Director of Field Hospitals, 28th Div.	Camp Hancock
Cushman, A. S., Lieut. Col.	Ordnance Dept., U.S.N.A.	Frankford Arsenal
Detwiler, Jas. G., 1st Lieut.	Infantry, U.S.R.	Fort Logan H. Roots
Eckert, S. B., Lieut.	Commander 9th Aero Squadron	France
Elliott, Henry M., 1st Lieut.	Ordnance Dept., U.S.R.	Western Cartridge Co.
Emerson, Geo. H., Colonel	In charge of Russian Railway Service Corps	Japan
Felton, Samuel M.	U. S. Director-General of Railways in connection with Expeditionary Force	Chicago
Ferguson, Walter B., Private	21st Co., 154th Depot Brigade	Camp Meade

Name and rank	Branch of service	Location
Fraser, Persifor, Ensign	U.S.N.R.F.	League Island
Gardner, H. A., Senior Lieut.	Naval Flying Corps	Washington
Gfrörer, A. H., 1st Lieut.	Ordnance Dept., U.S.R.	Washington
Gibbons, Joseph E., Private	Co. D., 103rd Engineers	Camp Hancock
Glendinning, Robt. E., Major	Aviation Section, Signal Corps	Overseas
Gribbel, W. G., Captain	Co. A., 30th Engineers, U.S.R. (Gas and Flame)	France
Griest, Thos. S., 1st Lieut.	1st Telegraph Battalion, Signal Corps, U.S.A.	France
Hall, R. T., Rear Admiral	U. S. Navy, Inspector of Machinery	Cramps' Shipyard
Hodges, Austin L., Capt.	Ordnance Dept., U.S.R., Experimental Officer on Artillery Ammunition	Frankford Arsenal
Howson, Richard, Sergeant	306th Ambulance Corps	Camp Meade
Ives, H. E., Captain	Signal Corps, U.S.A.	Washington
Jones, Jonathan, Captain	E.O.R.C., 23rd Engineers	Camp Laurel
Karrer, Enoch, Private	5th Company, 2nd Battalion 154th Depot Brigade	Camp Meade
Kennedy, M. C., Colonel	Deputy Director General of Transportation	France
Kent, S. Leonard, Jr., 2nd Lieut.	5th Engineers	Camp Lee
Kingsbury, E. F., 1st Lieut.	Aviation Section, S.O.R.C., Dept. of Science and Research	Washington
LeBoutillier, H. W., Private	Unit No. 10, Pennsylvania Hospital	France
Lichtenberg, Chester, 1st Lieut.	Engineer Reserve Corps, U.S.A.	Washington
Longstreth, Chas., Lt. Commander	U.S.N.R.F.	Philadelphia
McCoy, John F.	Aviation Section, Signal Corps	Princeton
MacLean, Malcolm R., 1st Lieut.	Co. 9, Officers' Reserve Corps	
Martin, Thos. S., 1st Lieut.	Ordnance Dept., U.S.R.	Washington
Masters, Frank M., Major	Ordnance Dept., U.S.R.	Washington
Maxfield, H. H., Lieut. Col.	19th Railway Engineers, U.S.N.A.	
Mershon, Ralph D., Major	E.O.R.C., U.S.A.	New York
Miller, Fred. J., Major	Ordnance Reserve Corps	Centre Bridge, Penna.
Owens, Major R. B.	Signal Corps	France
Parrish, T. R., 1st Lieut.	Signal Corps	Washington
Reber, Samuel, Colonel	Signal Corps, U.S.A.	New York
Richardson, Chas. E., 1st Lieut.	30th Engineers, U.S.R. (Gas and Flame)	France
Spackman, Henry S., Major	Engineer Officers' Reserve Corps	France
Spruance, W. C., Jr., Lt. Col.	Ordnance Dept., National Army	Chevy Chase Md.
Squier, Geo. O., Major General	Chief Signal Officer, U.S.A.	
Stanford, H. R., Civil Engineer	U. S. Navy	Boston
Thomas, Geo. C., Jr., Captain	Aero Service Squadron 96, Aviation Section, Signal Corps	France
Tilghman, B. C., Captain	A.D.C., 28th Div. Headquarters, U.S.A.	
Vogleson, J. A., Major	Sanitary Corps (Surgeon General's Dept.)	Fort Oglethorpe
Wagner, Fred. H., Major	Ordnance Reserve Corps, Nitrate Division	Washington
Wagner, Fred. H., Jr. Sergeant	Co. E., 304th Engineers	Camp Meade

Name and rank	Branch of service	Location
Wetherill, W. C., Ensign	U. S. Navy	
Widdicombe, R. A., Major	C.Q.M., Chemical Plant No. 4	Saltville, Va.
Wood, Edw. R., Jr., Captain	18th Field Artillery, U.S.N.A.	El Paso, Texas
Worrell, Howard Sellers	3rd Officers' Training Camp	Fortress Monroe
Wyckoff, A. B., Lieut.	U. S. Navy	Ontario, Cal.
Yale, A. W. Major	Medical Reserve Corps, Gas Division	Camp Kearney
Yorke, George M., Major	Signal Corps, U.S.R.	New York

MEMBERS DOING CIVILIAN WORK FOR THE UNITED STATES GOVERNMENT

Name	Appointment	Location
Akeley, Carl E.	Consulting Expert of Mechanical Devices, War Department	Washington
Anderson, Robt. J.	Engineer of Tests of Ordnance, War Dept., U.S.A.	Brier Hill Steel Co.
Balls, William H.	Ships Draughtsman	Phila. Navy Yard
Bancroft, Joseph	Secretary, Local Board No. 1	Wilmington
Baskerville, Charles	Working with Bureau of Mines, Ordnance Dept. (Gas Warfare, Shells, etc.)	New York
Bodine, Samuel T.	Vice-Chairman, District Exemption Board, No. 1, Eastern Judicial District of Penna.	Philadelphia
Brown, Lucius P.	Federal Milk Commission	New York
Burnham, George, Jr.	Dept. of Civilian Service and Relief, Public Safety Committee of Pennsylvania	Philadelphia
Charles, Bernard S.	Ordnance Inspector, U. S. Navy	Allentown, Pa.
Comey, Arthur M.	Chairman, Sub-Committee on Explosives, Chemistry Committee, National Research Council	Chester, Pa.
Condict, G. Herbert	Naval Consulting Board, Member Committee of Examiners	Plainfield, N. J.
Cooke, Morris L.	Chairman, Storage Committee of Munitions Board; Member on Staff, Emergency Fleet Corporation	Washington
Cope, Thomas D.	National Research Council	Washington
Day Charles	Member of Army War Council	Washington
Delano, Frederic A.	Member of Federal Reserve Board	Washington
Dickie, G. W.	Chief Inspector, U. S. Shipping Board, Moore & Scott Shipyard	Oakland, Calif.
Douredoure, B. L.	Student at Franklin Institute Radio School	Philadelphia
Dunn, Gano	Chairman, Engineering Committee, National Research Council	New York
Garrison, Frank Lynwood	Chairman, U. S. Manganese Commission	Philadelphia
Gilpin, Francis H.	Mechanical Engineer, Research Section, Picatinny Arsenal	Dover, N. J.
Halberstadt, Baird	Federal Fuel Administrator for Schuylkill Co., Penna.	Pottsville

Name	Appointment	Location
Hoskins, Wm.	Consulting Chemist, Advisory Committee, Bureau of Mines; Associate Member, Naval Consulting Board	Chicago
Hyde, Edward P.	National Research Council, Sub-Committee on Monocular vs. Binocular Field-Glasses (Chairman).	Cleveland
Insull, Samuel	Chairman, Illinois State Council of Defense	Chicago
Kennelly, A. E.	Conducting special course in radio-engineering for the U. S. Signal Corps, in conjunction with Prof. E. C. Chaffee	Harvard Univ.
Lloyd, E. W.	Asst. Secretary, Illinois State Council of Defense	Chicago
Lucke, C. E.	Civilian Director, U. S. Navy Gas Engine School	Columbia Univ.
Merrick, J. Hartley	Director, Bureau of Camp Service, Penna. Div., American Red Cross	Philadelphia
Milne, David	Treasurer, American Red Cross General Hospital No. 1	Philadelphia
Morris, Effingham B.	Treasurer, Committee of Public Safety, State of Pennsylvania	Philadelphia
Nichols, Carroll, B.	Fuel Administration	Washington
Nichols, Wm. H.	Committee on Chemicals, Advisory Council of National Defense, Consulting Chemist, Bureau of Mines	New York
Penrose, R. A. F., Jr.	Member of Geology Committee of the National Research Council	Philadelphia
Rapp, Isaiah M.	Special Investigator of Weights and Measures for the U. S. Food Administration	Norman, Oklahoma
Rautenstrauch, Walter	Committee of the National Research Council	New York
Richards, Joseph W.	Member of Naval Consulting Board	So. Bethlehem, Penna.
Robins, Thomas	Member and Secretary of the Naval Consulting Board	New York
Sperry, Elmer A.	Member of Naval Consulting Board	Brooklyn, N.Y.
Sprague, Frank J.	Member of Naval Consulting Board, Chairman, Committee on Electricity and Shipbuilding	
Stradling, George F.	Recruiting for Aviation Section, S.O.R.C.	Philadelphia
Swenson Magnus	Federal Food Administrator for Wisconsin; Chairman, State Council for Defense	Madison, Wis.
Talbot, Henry P.	Member of Advisory Board, Bureau of Mines (Gas Defense)	Cambridge, Mass.
Thomson, Elihu	National Research Council in coöperation with Council of National Defense	Swampscott, Mass.

Please send additional information and corrections to the Secretary.

COMMITTEE ON SCIENCE AND THE ARTS.

(Abstract of Proceedings of the Stated Meeting held Wednesday, March 6, 1918.)

HALL OF THE FRANKLIN INSTITUTE,
PHILADELPHIA, March 6, 1918.

DR. H. JERMAIN CREIGHTON *in the Chair.*

The following report was presented for first reading:

No. 2709.—The Fahy Permeameter.

The following reports were presented for final action:

No. 2656.—Automatic Operation of Water Gas Sets. Recommended that Edward Longstreth Medals of Merit be awarded to John Hawley Taussig, of Philadelphia, Pa., and to Charles Franklin Zeek, of Pensacola, Fla., for their inventions embodied in this device.

No. 2690.—Havard Coal Meter. Recommended that the Certificate of Merit be awarded to Oliver D. Havard, of Allentown, Pa.

GEORGE A. HOADLEY,
Acting Secretary.

SECTIONS.

Sections of Physics and Chemistry.—A meeting of the Section was held in the Hall of the Institute on Thursday evening, February 14, 1918, at 8 o'clock, with Mr. G. H. Clamer in the chair. The minutes of the previous meeting were read and approved.

C. W. Kanolt, Ph.D., of the Bureau of Standards, Washington, D. C., delivered a lecture on "Refractory Materials and High-temperature Measurements." A description was given of the measurement of high temperatures by means of thermocouples, resistance thermometers, and optical and radiation pyrometers. A report was given of research on various refractories and on the resistance of structures and structural materials to fire. The lecture was illustrated with lantern slides, and with samples of refractories and of apparatus used in high-temperature measurements.

The paper was discussed by Doctors Northrup and Kanolt, Professor Snyder, Mr. Fulweiler, and others. On motion of Doctor Hoadley, a vote of thanks was extended to Doctor Kanolt, and the meeting adjourned.

JOSEPH S. HEPBURN,
Secretary.

Sections of Physics and Chemistry.—A meeting of the Section was held in the Hall of the Institute on Thursday evening, February 28, 1918, at 8 o'clock, with Dr. Harry F. Keller in the chair. The minutes of the previous meeting was approved as read.

F. E. Wright, Ph.D., Captain of Ordnance, U. S. R., of the Geophysical Laboratory of the Carnegie Institution of Washington, delivered a lecture on

"The Production of Optical Glass for Military Purposes," describing the increase during the past year in both the quality and the quantity of American optical glass as the result of coöperation between the Geophysical Laboratory and the Bausch & Lomb Optical Company. A summary was given of the raw materials used, the process of manufacture, and the tests applied to the product. The communication was discussed by Doctors Stradling, Alleman, and Barton, Messrs. Benoliel and Patterson, Captain Wright, and others. A vote of thanks was extended to Captain Wright.

Mr. W. N. Jennings then described "The Rapid-fire Construction of the Cantonment at Camp Dix," showing a series of lantern slides of the cantonment taken by himself at various stages of its construction.

The meeting then adjourned.

JOSEPH S. HEPBURN,
Secretary.

MEMBERSHIP NOTES.

ELECTIONS TO MEMBERSHIP.

(*Stated Meeting, Board of Managers, March 13, 1918.*)

RESIDENT.

PROF. LEO LOEB, Mechanical Engineer, Day & Zimmermann, Inc., 611 Chestnut Street, Philadelphia, Pa.

MR. A. SAUNDERS MORRIS, Mechanical Engineer, Eighteenth Street and Allegheny Avenue, Philadelphia; and for mail, Haverford, Pa.

MR. JAVIER RESINES, Industrial Chemist, Eighteenth Street and Allegheny Avenue; and for mail, Hotel Stenton, Philadelphia, Pa.

NON-RESIDENT.

MR. LEWIS MARVIN DRAKE, Experimental Scientist, West Fairview Avenue, Daytona, Florida.

PROF. CLINTON NEVIUS LAIRD, Missionary, Educator, Chemist, Canton Christian College, Canton, China; and for mail, 3343 North Bouvier Street, Philadelphia, Pa.

LIBRARY NOTES.

PURCHASES.

BALL, SIR R. S.—Treatise on the Theory of Screws. 1900.

BYERLY, W. E.—Introduction to the Use of Generalized Coördinates in Mechanics and Physics. 1916.

COOPER, G. S.—By-product Coking. 1917.

CROFT, TERRELL.—Practical Electricity. 1917.

HATCHER, J. S., WILHELM, G. P., and MALONEY, H. J.—Machine Guns. 1917.

LITTLE, H. F. V.—Aluminium and Its Congeners, Including the Rare Earth Metals. 1917.

Moody's Manual of Railroad and Corporation Securities, vol. 19, part 1. 1918.
MORSE I. H.—Calculations Used in Cane-sugar Factories. 1917.
OSTWALD, WILHELM.—Fundamental Principles of Chemistry. 1917.
THORINGTON, JAMES.—Refraction of the Human Eye. 1916.
TSCHAPPAT, W. H.—Text-book of Ordnance and Gunnery. 1917.

GIFTS.

Ajax Manufacturing Company, Reference Book and Catalogue No. 15, and Bulletin No. 31. Cleveland, Ohio, no dates. (From the Company.)

Alberger Pump and Condenser Company, Bulletin No. 17. New York, 1913. (From the Company.)

Allis-Chalmers Manufacturing Company, Catalogue No. 106, Cyanide Plants and Equipment. Milwaukee, Wis., 1917. (From the Company.)

American Clay Machinery Company, American Standard Foundry Pan for Mixing or Grinding Sand for Gray Iron and Steel Foundries. Bucyrus, Ohio, no date. (From the Company.)

American Hard Rubber Company, Acid Pumps, Pipe and Fittings. New York, no date. (From the Company.)

American Institute of Mining Engineers, Transactions, vol. lvi. New York, 1917. (From the Institute.)

American Steel and Wire Company, Aerial Tramways. Chicago, Ill., 1917. (From the Company.)

American Well Works, Catalogue No. 149, Centrifugal Pumps. Aurora, Ill., 1917. (From the Works.)

Amherst College, Catalogue, 1917–18. Amherst, Mass., 1917. (From the College.)

Automatic Buffing Machine Company, Inc., Catalogue D. Buffalo, N. Y., no date. (From the Company.)

Bond Foundry and Machine Company, Catalogue No. 38, Power Transmitting Machinery. Manheim, Pa., 1917. (From the Company.)

Bond, Harold L. Company, Atlantic Pumping Engines for Contractors, Municipalities, and Corporations. Boston, Mass., no date. (From the Company.)

Butterfield and Company, Inc., Catalogue No. 16. Taps, Dies, Reamers, and Screw Plates. Derby Line, Vt., no date. (From the Company.)

Cambridge, Mass., Water Board, Annual Report, April 1, 1916, to April 1, 1917. Cambridge, 1917. (From the Board.)

Canada Department of Mines, Geological Survey, Memoir 99, Road Material Surveys in 1915, by L. Reinecke; Memoir 102, Espanola District, Ontario, by T. T. Quirke. Ottawa, 1917. (From the Survey.)

Canada Minister of Public Works, Report for the Fiscal Year Ended March 31, 1917. Ottawa, 1918. (From the Minister.)

Card, S. W. Manufacturing Company, Catalogue No. 28, Taps, Dies, Screw Plates. Mansfield, Mass., no date. (From the Company.)

Chicago Bureau of Public Efficiency, The Water Works System of the City of Chicago. Chicago, Ill., 1917. (From the Bureau.)

Connelly Boiler Company, Connelly Water Tube Steam Boilers. Cleveland, Ohio, no date. (From the Company.)

Cooper, C. and G. Company, Catalogue of Cooper Gas Engines, and Bulletin No. 54. Mount Vernon, Ohio, 1912. (From the Company.)

Curtis & Curtis Company, Pipe Cutting and Threading Machinery. Bridgeport, Conn., no date. (From the Company.)

Eclipse Fuel Engineering Company, Heat Treatment of Steel in Gas Furnaces, and the Heat Treatment of High-speed Steel, by Garnet W. McKee. Rockford, Ill., 1918. (From the Company.)

Eureka Machine Company, Eureka Concrete and Motor Mixers. Lansing, Mich., no date. (From the Company.)

Falls Machine Company. Falls Automatic Engine Stop. Sheboygan Falls, Wis., no date. (From the Company.)

Files Engineering Company, Inc., Files Hand Stoker. Providence, R. I., no date. (From the Company.)

Ganschow, William Company, Catalogue No. 26, Ganschow Gears. Chicago, Ill., 1915. (From the Company.)

Gilbert & Barker Manufacturing Company, Catalogue B, Gas Furnaces. Springfield, Mass., 1912. (From the Company.)

Gisholt Machine Company, Increasing Production with Gisholt Machines. Madison, Wis., no date. (From the Company.)

Greenfield Tap and Die Corporation, Bulletin No. 1, How to Measure Screw Threads; and Wells Self-opening Die. Greenfield, Mass., 1917. (From the Corporation.)

Hanson & Van Winkle Company, Catalogue No. 21, Electro-plating and Polishing Supplies. Newark, N. J., 1917. (From the Company.)

Harper and Brothers, The Harper Centennial, 1817–1917. New York, 1917. (From the Publishers.)

Helm Brick Machine Company, Concrete for Beauty, Adaptability, and Permanence. Cadillac, Mich., no date. (From the Company.)

Heræus Le Chatelier Pyrometer, Catalogue P, and Facts Worth Knowing About Pyrometers. New York, 1915. (From Mr. Charles Engelhard.)

Hoskins Manufacturing Company, Bulletins Nos. 1, 3, 3-A, 8, 10, and 12. Detroit, Mich., 1915–17. (From the Company.)

International Heater Company, Catalogues of Boilers and Furnaces. Utica, N. Y., 1910–17. (From the Company.)

Kennedy Valve Manufacturing Company, General Catalogue and Price List, 1916. Elmira, N. Y., 1916. (From the Company.)

Lackawanna Steel Company, Bulletin No. 108, Lackawanna Steel Sheet Piling. Lackawanna, N. Y., 1915. (From the Company.)

Langelier Manufacturing Company, Catalogue of Drilling and Tapping Machines. Arlington, Cranston, R. I., no date. (From the Company.)

LeBlond, R. K. Machine Tool Company, Catalogues, LeBlond Lathes, and Heavy Duty Crankshaft Lathes, and A Lesson in Economics. Cincinnati, Ohio, 1914–17. (From the Company.)

Leland Stanford Junior University, Annual Report of the President for the Twenty-sixth Academic Year Ending July 31, 1917. Stanford University, Calif., 1917. (From the University.)

Lupton's, David, Sons Company, Catalogue No. 9, Service Products; and Air, Light, and Efficiency. Philadelphia, 1916–17. (From the Company.)

McCord Manufacturing Company, Catalogue No. 18, Universal Window Devices. Detroit, Mich., no date. (From the Company.)

Milwaukee Tool and Forge Company, Tools for Service. Milwaukee, Wis., no date. (From the Company.)

Mitchell-Tappen Company, Standardized Metal Caging for Fireproof Buildings. New York, no date. (From the Company.)

Moloch Stoker Company, Catalogue of the Moloch Type "H" Stoker. Chicago, Ill., 1918. (From the Company.)

Mueller, H. Manufacturing Company, Ltd., The Men Behind the Man Behind the Gun. Port Huron, Mich., 1917. (From the Company.)

National Scale Company, The National Factory Systems. Chicopee Falls, Mass., 1917. (From the Company.)

New Jersey State Library, New Jersey Archives, First Series, vol. xxix. Paterson, N. J., 1917. (From the State Librarian.)

Newton Machine Tool Works, Inc., Catalogue No. 49, Newton Slotting Machines. Philadelphia, no date. (From the Works.)

New York Public Service Commission for the First District, Report for the Year Ending December 31, 1916, vol. i. Albany, 1917. (From the Commission.)

New York State University, Department of Education, Elementary Education, Report for the School Year Ending July 31, 1916, by Thomas E. Finegan. Albany, 1917. (From the New York State Library.)

New Zealand Government Statistician, Statistics of the Dominion for the Year 1916, vol. i: Blue Book, Population and Vital Statistics, Law and Crime. Wellington, 1917. (From the Government Statistician.)

North Western Expanded Metal Company, Hand-book for Formless Concrete Construction Using T-rib Chanelath. Chicago, Ill., 1918. (From the Company.)

Ohio Brass Company, Catalogue No. 16. Mansfield, Ohio, 1916. (From the Company.)

Ontario Bureau of Industries, Annual Reports for 1914, 1915, and 1916, parts i and ii. Toronto, 1915–17. (From the Bureau.)

Ontario Bureau of Mines, Twenty-sixth Annual Report, 1917. Toronto, 1917. (From the Bureau.)

Pennsylvania Railroad Company, Instructions Governing the Use of Explosives. Philadelphia, 1913. (From Mr. J. C. Johnson, Superintendent of Telegraph.)

Pennsylvania Society of the Colonial Dames of America, Committee on Historical Research, Forges and Furnaces in the Province of Pennsylvania. Philadelphia, 1914. (From Mrs. James M. Longacre, Chairman.)

Penrose, Charles, Station Safeguarding. Philadelphia, 1916. (From the Author.)

Princeton University, Catalogue, 1917–18. Princeton, N. J., 1917. (From the University.)

Savage Arms Company, Lewis Automatic Machine Gun, Model 1916. Utica, N. Y., 1916. (From the Company.)

Second Pan-American Scientific Congress, Proceedings, vol. vi, Section V. Washington, 1917. (From the Congress.)

Shuster, F. B. Company, Bulletin A, Automatic Wire Straightening and Cutting Machines. New Haven, Conn., no date. (From the Company.)

Smith College, Catalogue, 1917–18. Northampton, Mass., 1917. (From the College.)

Stevens Institute of Technology, Annual Catalogue, 1918–19. Hoboken, N. J., 1918. (From the Institute.)

Sturtevant Mill Company Separator Catalogue No. 77F, and Ring Roll Mill Catalogue No. 79C. Boston Mass., 1917. (From the Company.)

Sweet's Catalogue Service, Sweet's Engineering Catalogue, Fourth Annual Edition. New York, 1917. (From the Service.)

Trussed Concrete Steel Company, Kahn Road Book, and Kahn Building Products, Seventh Edition. Youngstown, Ohio, 1916. (From the Company.)

U. S. Coast and Geodetic Survey, Annual Report of the Superintendent for the Fiscal Year Ended June 30, 1917. Washington, 1917. (From the Survey.)

United States Electrical Tool Company, Catalogue No. 16, Portable Electrical Tools. Cincinnati, Ohio, 1917. (From the Company.)

University of Maine, Catalogue, 1917–18. Orono, 1917. (From the University.)

Walter Concrete Machinery Company, Inc., Walter Concretile, A Roof for All Time. Indianapolis, Ind., no date. (From the Company.)

Westinghouse Electric and Manufacturing Company, Catalogue 8-E, Industrial Heating Apparatus. East Pittsburgh, Pa., 1917. (From the Company.)

Wheeler, C. H. Manufacturing Company, The Radojet Air Pump. Philadelphia, 1918. (From the Company.)

Williams, D. T. Valve Company, Catalogue No. 10, Steam Specialties. Cincinnati, Ohio, 1915. (From the Company.)

Wilmarth & Morman Company, Catalogue No. 107, of Grinding Machinery. Grand Rapids, Mich., no date. (From the Company.)

Witte Engine Works, Catalogue No. 48, How to Judge Engines. Kansas City, Mo., no date. (From the Works.)

BOOK NOTICES.

FINDING AND STOPPING WASTE IN MODERN BOILER ROOMS. By Engineers of the Harrison Safety Boiler Works. Philadelphia, Harrison Safety Boiler Works, 1918. 274 pages, illustrations, tables, diagrams. 12mo. Flexible cloth. Price, $1.

Commercial engineering organizations and manufacturers of engineering specialties in recent times have given a great deal of attention to the publication of the strictly technical side of their interests, and some highly creditable technical literature is now to be found, either in bulletins or in catalogues, primarily issued for the purpose of exploiting the activities or the products of such firms. The present work is a publication of this type, originally intended as an appendix to the company's catalogue of Cochrane V-Notch Meter, which has grown to require a separate volume. In this handbook the best available contributions of engineers to technical periodicals, engineering societies and government publications have been collected in convenient form for ready reference. Among the latter, the excellent bulletins on the utilization of fuels issued during recent years by the United States Bureau of Mines have been freely drawn upon.

The work is divided into five sections: "Fuels," "Combustion," "Heat Absorption," "Boiler Efficiency," and "Boiler Plant Proportioning and Management." Under these headings a very wide range of information is covered, the subject-matter having been selected with a view to its service to owners, managers, engineers, and firemen in increasing and maintaining boiler-plant economy. The book has been compiled by George H. Gibson, assisted by Mr. Percy S. Lyon. The proofs were read by Mr. Henry Kreisinger, who conducted for the United States Bureau of Mines many of the investigations quoted in the text.

LUCIEN E. PICOLET.

PUBLICATIONS RECEIVED.

The Taylor System in Franklin Management Application and Results, by Major George D. Babcock, in collaboration with Reginald Trautschold, M.E., with a foreword by Carl G. Barth. 245 pages, illustrations, plates, tables, diagrams. New York, Engineering Magazine Company, 1917. Price, $3.

American Lubricants from the Standpoint of the Consumer, by L. B. Lockhart, consulting and analytical chemist. 236 pages, illustrations, 8vo. Easton, Pa., The Chemical Publishing Company, 1918. Price, $2.

Chemical French: An introduction to the Study of French Chemical Literature, by Maurice L. Dolt, Ph.D. 398 pages, 8vo. Easton, Pa., The Chemical Publishing Company, 1918. Price, $3.

Canada, Department of Mines, Mines Branch: Summary Report for the Calendar Year Ending December 31, 1916. 183 pages, illustrations, plates, tables, 8vo. Ottawa, King's Printer, 1917. Price, 25 cents.

Ontario Bureau of Mines: Twenty-sixth Annual Report, 1917, being volume 26. 366 pages, illustrations, plates, maps, 8vo. Toronto, King's Printer, 1917.

Finding and Stopping Waste in Modern Boiler Rooms, vol. ii. A reference manual to aid the owner, manager, and boiler-room operator in securing and maintaining plant economy. 274 pages, illustrations, 12mo. Philadelphia, Harrison Safety Boiler Works, 1918. Price, $1.

U. S. Department of Agriculture: Bulletin No. 586, Progress Reports of Experiments in Dust Prevention and Road Preservation, 1916. 78 pages, 8vo. Washington, Government Printing Office, 1918. Price, ten cents.

U. S. Bureau of Mines: Bulletin 135, Combustion of Coal and Design of Furnaces, by Henry Kreisinger, C. E. Augustine, and F. K. Ovitz. 144 pages, illustrations, 8vo. Bulletin 140, Occupational Hazards at Blast-furnace Plants and Accident Prevention Based on Records of Accidents at Blast Furnaces in Pennsylvania in 1915, by Frederick H. Wilcox. 155 pages, illustrations, plates, 8vo. Bulletin 159, Abstracts of Current Decisions on Mines and Mining Reported from May to August, 1917, by J. W. Thompson. 111 pages, 8vo. Monthly Statement of Coal-mine Fatalities in the United States, November, 1917. List of Permissible Explosives, Lamps, and Motors Tested Prior to December 31, 1917. Compiled by Albert H. Fay. 32 pages, 8vo. Washington, Government Printing Office, 1917–18.

Portland Cement Association, Concrete Pressure Pipe. 15 pages, illustrations, 8vo. Chicago, Association, no date.

Promotion of Export Trade, speech of Hon. Frank B. Kellogg, of Minnesota, in the Senate of the United States, Monday, December 10, 1917. 16 pages, 8vo. Washington, Government Printing Office, 1918.

Explosives Law and Negative-making. ANON. (*The Inland Printer,* vol. 60, No. 5, p. 629, February, 1918.)—Now that the government is demanding that photo-engravers take out a license and deposit a bond before they can use alcohol and nitro-cellulose for making collodion, some of the discarded processes of negative making have been under consideration as possible substitutes. Many of these tried-out processes were too slow, but with the aid of modern electric lighting equipment and quick-working lenses they might prove of value until the restrictions on the use of collodion materials are removed.

There are a number of early processes that might be improved in the light of modern knowledge and put into practical use, such as the calotype and Greenlaw's process, which furnished negatives on paper and which have their counterpart in some of the modern bromide papers. The great trouble with them is the difficulty of reversing unless a prism is used, which doubles the length of exposure. Negatives on glass supports might be made with albumen or gelatin as the medium of holding the sensitive salts, and here again comes difficulty in stripping the negatives. Of course, dry plates can be used, either gelatin or collodion, and where the number of negatives required is not great they are really economical. It is a splendid opportunity for the marketing of a reliable collodion dry plate, as a wet-plate operator can handle it so much more satisfactorily than a gelatin plate. In fact, the situation may bring out an entirely new method of negative-making. It is suggested that the term "nitro-cellulose" be not used, or "gun-cotton" either, as they sound too explosive. The proper word is "pyroxylin" for the soluble cotton used in collodion. Securing a license and giving bond for the continued use of collodion is, however, a more practicable means of insuring satisfactory results.

CURRENT TOPICS

A New Standard of Current and Potential. C. F. Alcutt. (*Proceedings of the American Institute of Electrical Engineers,* vol. 37, No. 2, p. 83, February, 1918.)—The increasing use of potentiometers in commercial service, especially in connection with the measurements of temperature by means of thermocouples, makes it very desirable to secure a substitute for the standard cell usually required by these instruments. The serious shortage of standard cells caused by the war has emphasized this need. Furthermore, it is being recognized that it is poor economy to use a costly precision standard in a commercial potentiometer which reads to three significant figures at the most.

The new standard which is proposed as a substitute for the standard in certain classes of direct-current measurements is essentially a Wheatstone bridge which will balance for but one value of the current. The device consists of a Wheatstone bridge comprising three constant resistances, and a fourth element whose resistance is a function of the current flowing through it. In practice the resistance element consists of an evacuated glass bulb which encloses a fine filament of material having a relatively high temperature-coefficient of resistivity. The practicability of the device depends on securing a variable resistance having the desired current-resistance characteristics, together with a high degree of permanence. A bridge of this type was designed to balance with a current of 20 milliampères, and having just one volt potential difference when the bridge is balanced. The work done in connection with the development of this new standard has demonstrated that it may be relied upon to maintain an accuracy of plus or minus 0.1 per cent.

A Patent Abuse. Anon. (*Journal of Industrial and Engineering Chemistry,* vol. 10, No. 3, p. 2, March, 1918.)—The exigencies of the war period have led to feverish activity in many laboratories in attempts to carry out processes described in the literature and in patent specifications, chiefly in the field of organic chemistry. Within the past year we have frequently been apprised by chemists of the lack of success in the preparation of compounds by following directions, even by most careful attention to the minutest details, in the official records. Men who have experienced this difficulty stand so high that no question of lack of skill and technique can be involved, and we are forced to the conclusion that deliberate misrepresentation has been made, especially in the case of certain foreign patents. If this is true, it is extremely regrettable that the literature of chemistry is clogged with such deceit; in the case of patent specifications it is reprehensible, in that a matter of perjury is involved. The demonstration of such falsity would immediately invalidate the patent, but this is a tedious process, necessitating a great amount of laboratory work and expense and loss of time in litigation.

Our patent system should be protected against impositions. This might be accomplished in one of at least three ways: *First,* the Patent Office might test the good faith of all applicants for chemical patents by making greater use of existing government laboratories. It is doubtful, however, in view of the work already engaging the attention of these Federal laboratories, whether a further tax upon their courtesy would be justifiable. *Second,* the Patent Office might be provided with a control laboratory of its own. The varied character of the applications for patents covering all fields of chemistry would necessitate a large, efficiently manned laboratory. This would entail considerable expense, nevertheless it would be an expenditure operating for the benefit of the entire country. *Third,* the Patent Office might require of the applicant a laboratory demonstration of the correctness of the specifications. This would place the burden of the proof upon the inventor, but would work no hardship upon organizations having extensive laboratories, though it might affect the man of small means.

Perhaps there are other practicable remedies. Certain it is that the abuse should be eliminated, and the first step toward this end is the demonstration of the correctness of the original premise; namely, that the Patent Office files have been befouled with false declarations. If evidence can be brought together, we are fortunately in position to place it where it will do most good, and we therefore urge all chemists who have been led up a blind alley by following the directions outlined in patents to communicate that fact to this office, designating by number and subject the misleading patent, and supplementing this by a brief exposition of the difficulties encountered. This is more than an invitation, it is an appeal, for nothing can be more vital to the future of the chemical industries than the establishment upon a firm basis of the patent system, whose *raison d'être* is the stimulation of the inventive genius of the nation by affording full protection of the law to those who record with it the truth concerning their discoveries.

The Peat Deposits of the United States. ANON. (U. S. Geological Survey, *Press Bulletin,* No. 358, March, 1918.)—According to the United States Geological Survey, Department of the Interior, the commercial development of the vast peat deposits in the United States would materially relieve our present shortage of fuel. Although peat has never been largely used as fuel in this country because of our abundant supply of coal, which can be more readily prepared for consumption and in normal times more cheaply brought to the consumer, it has long been used in Europe, where 15,000,000 to 20,000,000 tons are consumed annually in generating heat and power.

The attempts made in this country to manufacture peat fuel on a commercial scale have not been successful, but the failure appears to have been due not to a lack of market for the product, but to the lack of sufficient capital, to the inexperience of the operators, and to preventable engineering errors. It is said that air-dried machine peat, which is but little inferior in calorific value to many grades of lignite coal, can be produced at a cost ranging from 75 cents to $2.50 a ton, the exact figure depending on the size and the efficiency of the plant; and it is believed that in some parts of the country it could successfully compete with other fuels for both domestic and industrial use. It burns with little smoke and ash, and wherever it has been used in this country it has proved very satisfactory and has found ready sale as fast as it has been produced.

The wide interest felt in the larger use of peat in the United States is expressed in recent messages from the governors of Maine and Massachusetts to the legislatures of those states, recommending an investigation of the local deposits of peat and its possible use to relieve the present shortage of fuel. The lack of other fuel in many European countries is now being supplied in part by an increased use of peat. According to United States commerce reports, 216 peat machines were in operation in Norway in 1917, compared with 55 in 1916 and 36 in 1914. Among these were two automatic machines, each costing $13,400, having a daily capacity of 30 to 40 tons of fuel, and requiring only two men for its operation.

Peat consumed in a properly designed gas producer yields gas of good quality and in abundant quantity in comparison with the yield from coal, as well as many valuable by-products. This is perhaps the most effective utilization of peat fuel for generating heat and power, because peat that is to be used in this way does not need to be so carefully prepared nor so thoroughly dried as peat that is to be consumed under steam boilers.

Specific information with regard to the use of peat in gas-producing plants and for other purposes is given in a bulletin prepared under the supervision of the United States Geological Survey but published as Bulletin 16 of the Bureau of Mines, from which copies of it may be obtained.

The Value of Models. ANON. (*Scientific American*, vol. 118, No. 8, p. 168, February 23, 1918.)—At one time a model was considered only as an interesting feature of the museum or the exposition. To-day a model is looked upon as a prerequisite for the undertaking of many an important piece of work. In such case it serves to translate the technical details of orthographic drawings into a miniature of the projected work, thus relieving the mind of the effort of visualizing the project from the plans in considering the merits of a given arrangement of the component elements of the project.

In the planning of country estates the work of the model maker is of paramount importance. Plans mean next to nothing to the average man, and, though wash-drawings convey a more understandable impression of the subject, the advantages and faults of an undertaking are much more prominently shown in a model from which the relationships of each detail may be at once seized. In the planning of large buildings the model has very definite application. Such buildings as the Woolworth skyscraper had been reproduced in miniature long before the structure raised itself above the crowded sidewalk of Broadway. Model skyscrapers have enabled many a prospective owner to appreciate what he was ordering.

Copper Castings for Electrical Purposes. G. F. COMSTOCK. (*Proceedings of the American Electrochemical Society,* October 4, 1917.)—Before the work of Matthiesson in 1860 the resistance of the usual grades of copper, even in the form of wire, was only about 50 per cent. of the standard which we have to-day. This work by Matthiesson emphasized the importance of eliminating all possible traces of impurities from copper to be used for conducting electricity. For instance, he found the conductivity of copper with 1.6 per cent. zinc to be only about 79 per cent. that of pure copper, both being in the form of wire. With 1.3 per cent. tin it was decreased to about 50 per cent., with 0.1 per cent. aluminum to 76.5 per cent., and with 0.5 per cent. iron to 36 per cent., while only 0.13 per cent. phosphorus decreased the conductivity to 70 per cent., and even traces of arsenic to 60 per cent.

In order to obtain copper wires of high conductivity it is necessary only to start with extremely pure copper bars. Two difficulties are encountered when this is attempted. First, sound castings are almost an impossibility, and, second, the pure metal in the cast condition is too soft and weak to give the best satisfaction in most electrical uses. The difficulty of obtaining sound castings of pure copper is caused by its rapid absorption of oxygen and other gases when it is melted. The gases not only dissolve in the molten metal, but copper oxide is also formed which is held in solution until the metal freezes. The second difficulty of softness and weakness cannot be overcome except by adding some other metal to the copper, thus making it no longer pure, or by giving the casting some mechanical treatment, such as forging, after which it is, properly speaking, no longer a casting.

Zinc is the element most often used for the purpose of deoxidation, thereby producing sound castings fairly easily with the minimum reduction in conductivity. Such castings deoxidized by zinc had a considerably lower conductivity than copper wire, in many cases only about 40 to 50 per cent. Phosphorus and silicon have both been used in place of zinc, and, while very small quantities of either are normally sufficient, their use is attended by the disadvantage that an excess of either of these elements does more harm to the conductivity than an equal excess of zinc. The use of silicon has for several years been under investigation with promising results; 75 to 85 per cent. conductivity has been obtained for castings deoxidized with silicon.

Two Million More Horsepower from the Niagara River. R. G. SKERRETT. (*Scientific American*, vol. 117, No. 26, p. 489, December 29, 1917.)—According to the estimates of government experts, it is physically possible to develop at Niagara Falls a maximum of 6,500,000 horsepower, but because of international agreement the legal maximum cannot exceed 790,000. As a matter of fact, because of various hampering circumstances, the total energy actually available for commercial service probably does not exceed 550,000 horsepower. The difference between fact and potentiality is the price paid for scenic beauty. The public generally, time and time again, has registered its vigorous protest against any impairment of this natural wonder. Engineers, therefore, have striven to find acceptable solutions of this economic problem, and among the latest is what is known as the Thomson-Porter Cataract project. Additional hydro-electric energy has become an acute national necessity, and Dr. T. Kennard Thomson, the engineering sponsor of the plan, is satisfied that the scheme in question will make it possible to obtain the desired power without in any wise detracting from the charm of Niagara Falls.

Briefly, the fundamental feature of the project is a massive dam rising from the rocky bed of the Niagara River and blocking the gorge from bank to bank at a point a little more than 4½ miles below the famous Cataract and something like 2½ miles south of Lewiston, N. Y., and Queenston, Ontario. By means of this dam the water level would be raised high enough above the present surface of the river to provide an effective head of 90 feet. The local result would be to lower the visible rise of the flanking cliffs by something like one-third, but the new level would merge exactly with the existing water surface at the Falls, and would therefore in no wise change the scenic conditions there. The existing Rapids would, necessarily, be submerged, but the scheme contemplates substitute rapids below the dam that would be equally tumultuous and probably more spectacular.

The hydro-electric installation, that would be made practicable by the building of the proposed dam, would develop quite 2,000,000 horsepower, and one-half of this would be for the United States and the other half for the Dominion of Canada. Assuming a horsepower to call on an average for the consumption of 10 tons of coal a year, the energy so obtained would be equivalent to the conserving of 20,000,000 tons of fuel annually. According to Doctor Thomson's figures, it would cost substantially $100,000,000 and take three years to rear the dam and to build and equip the associate hydro-electric plants for the development of 2,000,000 horsepower.

Tin in Virginia. ANON. (U. S. Geological Survey, *Press Bulletin,* No. 359, March, 1918.)—The United States is almost entirely dependent on foreign countries for its supply of tin. As this metal is a wartime necessity, and as a domestic source of supply is urgently needed, all known deposits of tin ore (cassiterite) in the United States have recently been examined by geologists of the United States Geological Survey, Department of the Interior. One of the most promising of these deposits is in the Irish Creek district, in the eastern part of Rockbridge County, Virginia, near the summit of the Blue Ridge. This deposit was recently examined by H. G. Ferguson, of the United States Geological Survey, which in this research is acting in coöperation with the Virginia Geological Survey. Mr. Ferguson's report has been published as Bulletin XV-A of the Virginia Geological Survey.

The existence of tin ore in the Irish Creek district has been known for many years, and between 1883 and 1893 the deposit there was actively mined. The mining company, however, became involved in litigation as to land titles and abandoned work in 1893. Work on the deposit was never resumed, and the old workings are now caved and heavily overgrown with brush, so that a thorough examination of them is difficult, but what Mr. Ferguson saw in the field and the information he derived from old reports led him to conclude that the deposits along the Blue Ridge in this vicinity offer some promise as a source of tin, both through the systematic working of the known veins and the possible discovery of other deposits.

The cassiterite occurs in quartz veins that cut a granitic rock of peculiar appearance known as a hypersthene granodiorite. The veins do not continue for long distances, and their content of tin is probably very irregular from place to place. Some high-grade ore was found, however, and some tungsten ore occurs with the cassiterite. It is believed that the district is worthy of further investigation.

A copy of the report, Bulletin No. XV-A of the Virginia Geological Survey, may be secured on application to Dr. Thomas Leonard Watson, Director, Virginia Geological Survey, Charlottesville, Va.

Adirondack Gold and Platinum Sands. ANON. (*U. S. Geological Survey Press Bulletin,* No. 345, December, 1917.)—The United States Geological Survey, Department of the Interior, has received during the last few months a number of letters asking about supposed gold and platinum sands in the Adirondack Mountains. It appears that the falsity of the statements concerning the possibility of working these sands commercially has not been made clear, even after 30 years of effort.

In 1910 Dr. J. M. Clarke, the state geologist of New York, said, "The traces of gold found there [in the Adirondacks] do not afford any adequate basis for mining enterprise." This statement was reiterated in a letter from Doctor Clarke to the National Research

Council, dated July 16, 1917, from which the following extract is made:

"Platinum has been known to exist in small quantities in the sands of northern New York, but the amount is imperceptible and determinable only with difficulty. The platinum story is a veritable 'chestnut,' which has grown exceedingly unpalatable with the years. It has had a new birth this year, and I have already sent out notices to various 'investors,' advising caution in regard to the matter. In fact, within the last two months I have sent a carefully prepared statement to every newspaper printed in the state of New York, urging that no attention be given to the present reports as to the alleged new processes of winning gold and platinum from the sands of northern New York. Philadelphia has been the hotbed of some of the worst propaganda regarding gold and silver in New York that this country has known, and I am speaking within limitations in saying that millions of dollars have been wasted upon investment projects in New York, floated by crooked companies claiming to carry on their demonstrations right under the eye of the intending investor. The story of these 'gold crazes'—one after another, first on the east side of the Adirondacks, then on the west side; at the present time in Herkimer and St. Lawrence counties, while the Lewis County craze is not even yet dead—is a perfectly wicked one. . . . I have on my files the whole history of the transactions—sworn affidavits and confessions of copartners in these gold and platinum propaganda—and I have been going through this thing for the last 30 years, so I am speaking with some knowledge."

The following is a copy of the press bulletin mentioned by Doctor Clarke, issued by the State Geological Survey of New York, May 22, 1917:

"Another effort to arouse interest in the alleged gold-mining operations in this state has been brought to the attention of the state geologist, who on several occasions has warned the public against entering into schemes of this sort. The latest venture has its headquarters in Herkimer County, but nearly all sections of the Adirondacks and various other parts of the state have been exploited by promoters of these ill-founded enterprises, which in several instances have entailed very serious financial losses to the deceived investors. As an additional lure the promoters are now advertising that the sands contain platinum, whose value exceeds many times that of gold. The office of the state geologist has been in touch with this matter from the first, and its records show that there has never been any success attained in such workings, which, at best, contain only mere traces of the precious metals."

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FOOD WASTES—SOME CAUSES AND REMEDIES.*

BY

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It has been so often repeated in these latter days that "Americans are a wasteful nation" that we have become rather proud of the reproach and apparently have come to glory in our fancied strength in wasting what others must save. Inasmuch as we produce more food per man, though not per acre, than any European country, there has been a certain amount of reason for wastefulness, because it has actually cost us more to save than to waste.

But the outbreak of the great war has raised the price of labor by lessening the supply; it has been withdrawn even from the high-priced lands of Europe; the low-priced and fertile lands of the United States must feed practically all the civilized world with a lessened and ever-lessening labor supply. Well-being is almost coming to be measured no longer in terms of the counters called money, but in pounds of sugar or barrels of flour, because those essentials to the maintenance of life are apparently becoming constantly less abundant in relation to gold. Our days of plenty are gone for many years, and it is quite certain that by the time they return Americans will have so learned food thrift

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* Presented at a meeting of the Section of Physics and Chemistry held Thursday evening, January 24, 1918.

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that never again will Nature's gifts be so lavishly thrown about. Aforetime, if persons with a financial competence did not set a lavish table they were "mean and stingy"; now they are exercising the highest form of patriotism. Seriously speaking, however, American wastes of all sorts have been gross, and since now we must follow a different plan, I shall hope to indicate some steps in its beginning.

It will be quite obvious, from a moment's thought, that preventable wastes in foods are almost illimitable in number and kind. They exist wherever food is produced and handled. They will always exist until human nature in the mass undergoes those changes for the better which we all endeavor to compass in our individual lives. They originate in bad farm management, continue in the planting, cultivating, and harvesting of crops, in their transportation, marketing, and wholesale and retail distribution, and in the homes. In this paper we expect to confine our precise inquiry to those which occur in harvesting, in manufacture, in transit and distribution, and in the kitchen—in other words, after the crop has matured.

Table I (pp. 588 and 589) is a partial analysis in diagrammatic form, showing what are probably the principal causes of wastes.

It is a platitude to suggest that this subject is of much more importance to us just now than at any time in the past, or, God willing, at any future time which we here to-night are likely to see. Our 1917 crops were large. They yielded:

	Bushels
Corn	3,159,494,000
Wheat	650,828,000
Oats	1,587,286,000
Barley	208,975,000
Rye	60,145,000
Potatoes	442,536,000
Peanuts	60,222,000
Total	6,169,486,000

Our chief perishables were as follows:

Onions	13,554,000 bushels
Cabbage	502,000 tons
Peaches	45,066,000 bushels
Pears	13,281,000 bushels
Oranges	12,832,000 boxes
Apples	58,203,000 barrels

It is estimated that the Allies should get from some source 577,000,000 bushels of wheat and 674,000,000 bushels of other cereals, or a total of 1,251,000,000 bushels. Competent authority has suggested that 10 per cent. of all crops grown are wasted, which, on the basis of perishables and non-perishables above suggested, indicates that from this source alone, if we were able absolutely to stop waste, we could supply a very perceptible proportion of what is needed.

That this is possible is shown by the application of household economies already forced by high food prices of the past three years. The figures of garbage collected in three boroughs of the city of New York show a reduction for the year 1917 over 1916 of 8 per cent. In Boston, during three months of 1917, as compared with the previous year, there was a reduction of 12.3 per cent., while in New Haven, during 1917, there was an estimated decrease during a part of the year of about one-third. A short study made by me of the actual losses of materials which were good when they went into the garbage pail in New York City gives the surprising figure of $50 per load as the average, ranging from $20.80 to $61. This reduction of garbage, therefore, actually means a saving in money of over one million and a half of dollars. Let us hope that it is an earnest of what we can really do in conservation when we try.

Although not strictly pertinent to our discussion, it will be profitable for us to note some important preventable wastes in production alone, such as the prevalence of cholera in hogs and of tuberculosis and contagious abortion in cattle. Again, it costs one-third less in food and labor to make milk from a high-producing than from a low-producing cow. Akin to the same sort of bad management which maintains the poor cow are such things as the failure to take proper care of a fruit crop by spraying, the raising of poor varieties of fruits and vegetables, bad judgment in the selection of crops for localities and soils, and the like. Most of these are susceptible of reasonably prompt rectification. Correction of the others means that slow process of education and scientific investigation carried on by the Agricultural Colleges' extension work, investigation in the experiment stations, and like activities which already have been so successful.

The layman would suppose wastes of the sort we are discussing are to be expected chiefly or solely in perishables, such as vege-

TABLE I.

Partial Analysis of Food-waste Problem.

Prepared by Lucius P. Brown, Director of Bureau of Food and Drugs, Department of Health, New York City.

WASTES OF FOOD OCCUR IN ITS HANDLING AND UTILIZATION FROM THE FOLLOWING CAUSES.

I. In Producer's Hands	A. On Farm	1. Growing Conditions	a. Unfavorable weather, weakening plant.
			b. Insect pests or micro-organism infection.
		2. In Harvesting	a. Excessive rains or drouth at time of packing.
			b. Shortage of labor.
			c. Too long storage before shipment.
			d. Storage under unfavorable conditions before shipment.
			e. Too early harvesting.
			f. Holding of cars too long because of shortage of labor.
		3. Poor Packing	a. Due to unskilled labor.
			b. Due to shortage of labor.
			c. Rough handling of filled package.
			d. Unsuitable or poorly made containers.
			e. Poor grading.
		4. Shipping Defects	a. Undue holding of cars to secure carload freight rates.
			b. Overloading of cars.
			c. Poor judgment or carelessness in placing packages in car.
	B. From Woods and Waters	1. Catching of young fish.	
		2. Same causes as shown under 1A-2c; 1A-2d; 1A-3d.	
		3. Failure to properly ice.	
	C. In Factory	1. Spoilage from insanitary conditions.	
		2. Spoilage due to unskilled labor or labor shortage.	
		3. Insufficient number or poor quality of containers.	
		4. Failure to use by-products.	
II. In Transit (in hands of transportation companies)	A. At Shipping Point	1. Shortage of cars.	
		2. Congestion on loading trucks.	
		3. Holding at foreign ports for ships.	
	B. In Handling Trains (Domestic Products chiefly)	1. "Slack" Management	a. Poorly designed or improper cars.
			b. See also 1A-4c.
			c. Trains skipping icing stations.
		2. Defects in Handling	a. Refrigeration defective or lacking altogether.
			b. Cars not rendered frost-proof.
		3. Delays in Transit	a. Due to poor management.
			b. Due to strikes, etc.
			c. Due to floods, storms, etc.
	C. In Ocean Transit	1. Damage by enemy boats.	
		2. Use of unsuitable ships or ships without refrigeration.	
		3. Slow voyage because of scarcity or high price of coal.	
		4. Poor stowing in holds, or stowing near boilers.	
		5. Stowing with heating cargo (*e.g.*, sugar).	
		6. Distant markets (with consequent long voyage) because usual markets are shut off by embargo or blockade.	
		7. Damage by marine accidents, such as collisions, fires, leaks, storms, etc.	
		8. Loading or discharge of perishable cargoes under unfavorable weather conditions.	
		9. Damage by transshipment because no direct line to destination.	

II. In Transit (in hands of transportation companies)	D. After Arrival at Destination	1. Congestion at Piers or Other Terminals	a. Due to track shortage. b. From undue length of demurrage. c. Strikes or other labor troubles. d. Due to shortage of storage space for goods.
		2. Ill-advised Reconsignment.	
		3. Undue Holding of Cars	a. Through slack management. b. To profit by market changes (at consignee's order).
		4. Abandoned by Consignee	a. Wholly unsound. b. Partly unsound and overhauling not profitable. c. Partly unsound but facilities to salvage unavailable. d. Market conditions believed to be unfavorable.
		5. Rough handling at terminals.	
III. In Distribution (from hands of transportation company to consumer)	A. Wholesale	1. Holding too long. 2. Inefficient care. 3. Poor storage facilities. 4. Goods stored in poor condition. 5. Overstocking. 6. Damage by rats, insects, etc. 7. Failure to remove promptly from terminals.	
	B. Retail	1. Carelessness or inefficiency. 2. Through fancies of customers. 3. Due to trimming, etc. 4. Overstocking. 5. Exposure to dust and insects.	
IV. In Kitchen	A. Hotel or Restaurant Kitchen	1. Stale bread thrown away. 2. "Slack" business methods. 3. Portions too large and too many gratis "side-orders." 4. Too much variety in dishes or single items, *e.g.* bread. 5. Overstocking. 6. Influence of custom, *e.g.* serving sugar on table. 7. Improper disposal of waste products, *e.g.* burning of garbage. 8. "Aging," and consequent loss in trimming, of meats.	
	B. Private Family	1. Unbalanced ration. 2. Letting good food go into garbage pails and sinks. 3. Poor facilities for and ignorance in handling foods. 4. Poor cooking.	

Wastes in the Food Supply, due to Economic Reasons and resulting therefore in loss of money to the consumer, occur in Trade Channels in part from the following causes:

A. No Terminal Markets.
B. Duplication of Marketing Facilities.
C. Expensive Cartage.
D. High retail delivery costs.
E. Unnecessary credits.
F. Extravagance in service and display.
G. Failure to buy home-packed goods of equal quality.
H. Failure of retailer to use proper merchandising methods.

tables, fruits, and eggs, but they are surprisingly large in the more stable foods, such as cereals, beans, etc.

As a somewhat extreme instance of poor marketing methods with resultant loss, it will pay us to follow closely what happens to eggs, in order to get the principles in our minds. It is estimated that the actual annual loss of eggs in the United States is about $50,000,000, or about two billion eggs, which means 20 eggs for every man, woman, and child in the United States. New York City's record will bring the matter to less overwhelming and therefore more understandable figures. The city's annual receipts are 5,000,000 cases, or 150,000,000 dozen. Breakage alone, due to shipment, is about 3½ per cent., which is 5,250,000 dozen, or about enough to furnish each inhabitant of the city with one egg for breakfast once a month. Inasmuch as this waste has not been stopped, neither I nor most of my friends have been able to have our monthly breakfast egg of late. That this is not a loss to the consumer and distributer alone is shown by the fact that at an Interstate Commerce Commission hearing held in the city in 1915 it was shown that the receiver's claims for breakage varied, on one of the railroads, from 8 to 60 per cent. of the monthly gross revenue from the business.

Loss in eggs begins before laying, for, if the farmer fails to separate his male birds from the laying flock, the eggs are fertile. A fertile egg begins to spoil at 70° F., because the life processes begin at that temperature, and an infertile egg will, under those late spring and summer temperatures which are so fatal to the egg supply of the South and Southwest, keep 10 to 20 days longer than the fertile one.

Remembering this, let us follow our trail of the egg. Of course, much the larger proportion of the supply comes from those farms where it is an incident to the general business. Usually the collections are made daily, but even then a very large proportion is from stolen nests in the fence-corners or the haymow, and in such event even daily collections furnish eggs of a varying vintage. The farmer's wife sells either to the travelling pedler or huckster or to the village store. In either case there is a certain amount of holding, and sometimes such holding (which is never under refrigeration) is in the hope of higher prices, and for as long as six weeks. The travelling collector is usually an agent or patron of the produce dealer in one of the larger towns.

His problem is not so much one of finding a market as of getting a supply. He is therefore loth to test his eggs by candling, because he does not care to risk the displeasure of the farmer's wife and so the loss of his farm supplies. In setting his purchase price, knowing as he does the losses he may expect, he makes an average figure such that the sound eggs of the careful and honest woman bring the same price as those of the other kind—which is the beginning of the actual money loss. There is some breakage before he gets his load to the produce dealer and (especially if he strikes a spell of hot weather) loss from spoilage, for his round trip rarely lasts less than a week. If, on the other hand, the eggs are taken to the country store, the transaction is mostly one of barter. Though the merchant has a double chance for insurance, he still needs doubly the business of the woman producer and applies the same principles as the huckster. The country merchant holds the eggs in a tub or box in the back of the store until it is convenient to ship by rail or road, resulting again in breakage and spoilage. He, too, trades with a produce dealer in a large town. The latter, if he is careful, candles for quality and sorts as to appearance. Thence the eggs go in car or smaller lots to the large consumption points, where they receive a final sorting: the cracked and dirty eggs are taken out, as well as the really unsound ones; sometimes they are even sorted according to color, for apparently a brown egg agrees with the digestion of Boston better than with that of New York. The final consumer's product, of course, bears most of the cost of all this, for the demand for off-grades is of a less stable character and at a necessarily much lower price. All this trouble, too, forces minor expenses to be paid out of the business, such as the additional cost imposed by careful sorting, the costs imposed on trade associations in efforts to stabilize the business and regulate the careless or dishonest dealer, as well as costs to the community imposed in enforcing food laws controlling the wholesomeness of the product. It is estimated that the losses in the various hands are distributed about 50 per cent. to the producer, while the shipper, the carrier, and the distributer divide the rest.

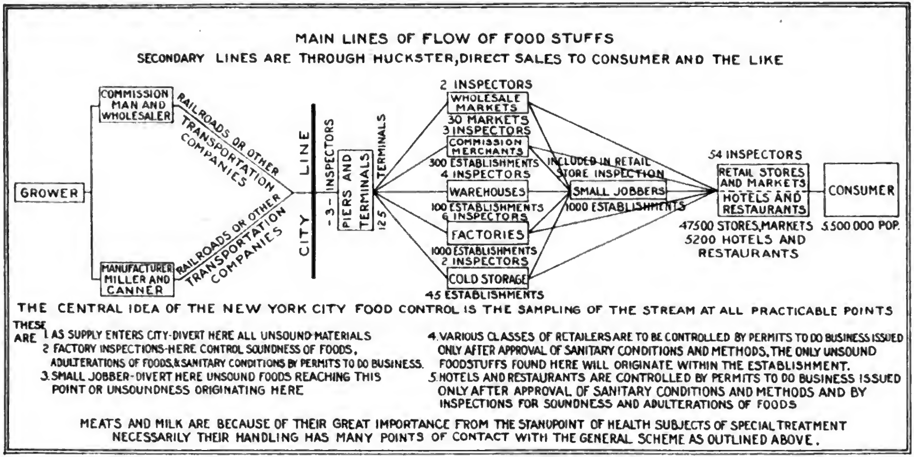
Fortunately for the foodstuffs trade in general, the handling of most perishables is either not so complicated as this or has become better systematized. The usual course for goods grown in the United States is from the farmer to the commission man or wholesaler, thence to the small jobber, to the retailer, and to the consumer or restaurant, and it is essentially under these heads we shall make our examination.

Wastes in the purely marketing end of the business cannot be better illustrated than by the experience of the New York City Health Department's Bureau of Food and Drugs under its recently inaugurated system of inspection. This bureau is charged with the duty of controlling the quality and purity of the food supply of that city, and in order to do this most effectively it has considered the food supply as a stream and examines this stream at every available point from producer to consumer. Obviously, in the case of a city, it can, as a practical proposition, go back to points of production only in the case of certain commodities having a very direct public-health bearing, such as milk. It therefore begins with the sampling of the food stream as the food comes across the city line, according to the scheme shown in Fig. 1. The force for inspection is subdivided into a number of districts, somewhat on the plan of police precincts, and, in addition, there are squads assigned to special work. There are two permanent squads, one of which is assigned to the railway and steamship terminals (which means, in New York City, largely the piers on the Hudson and East rivers, both in Manhattan and Brooklyn) and the squad assigned to control of factories. The duty of the Terminal Squad is to prevent unsound or damaged foods from entering the city, and of the Factory Squad, which has charge also of warehouses, to see that unsoundness originating within the city is properly controlled. The Terminal Squad is instructed whenever unsound material is found to inquire into the reasons for this unsoundness and to make a report thereupon with a view to correction of conditions through advice to shippers or transportation companies.

It is illegal for unsound food to come into the city. Therefore, when a lot wholly unsound is found, it is at once condemned and ordered destroyed; a lot partly unsound is placed under embargo and the holder is ordered to separate the sound from the unsound portions. Price levels will then determine whether the holder will carry out this order or abandon the goods to be destroyed.

I cannot better indicate to you the extent of preventable losses than to call attention to the table of the kind, amounts and values

FIG. 1.



THE CENTRAL IDEA OF THE NEW YORK CITY FOOD CONTROL IS THE SAMPLING OF THE STREAM AT ALL PRACTICABLE POINTS

THESE ARE
1. AS SUPPLY ENTERS CITY-DIVERT HERE ALL UNSOUND MATERIALS
2. FACTORY INSPECTIONS-HERE CONTROL SOUNDNESS OF FOODS, ADULTERATIONS OF FOODS & SANITARY CONDITIONS BY PERMITS TO DO BUSINESS.
3. SMALL JOBBER-DIVERT HERE UNSOUND FOODS REACHING THIS POINT OR UNSOUNDNESS ORIGINATING HERE
4. VARIOUS CLASSES OF RETAILERS ARE TO BE CONTROLLED BY PERMITS TO DO BUSINESS ISSUED ONLY AFTER APPROVAL OF SANITARY CONDITIONS AND METHODS. THE ONLY UNSOUND FOODSTUFFS FOUND HERE WILL ORIGINATE WITHIN THE ESTABLISHMENT.
5. HOTELS AND RESTAURANTS ARE CONTROLLED BY PERMITS TO DO BUSINESS ISSUED ONLY AFTER APPROVAL OF SANITARY CONDITIONS AND METHODS AND BY INSPECTIONS FOR SOUNDNESS AND ADULTERATIONS OF FOODS

MEATS AND MILK ARE BECAUSE OF THEIR GREAT IMPORTANCE FROM THE STANDPOINT OF HEALTH SUBJECTS OF SPECIAL TREATMENT NECESSARILY THEIR HANDLING HAS MANY POINTS OF CONTACT WITH THE GENERAL SCHEME AS OUTLINED ABOVE.

Sketch of system for control of food supply as used by the Bureau of Food and Drugs, Department of Health of New York City.

of foods actually condemned in the city during the year 1917, shown in Table II.

TABLE II.

Condemnations of Foods During 1917 by Department of Health, City of New York.

	Amount (pounds)	Cost
Meat	538,531	$115,409
Fish	362,280	18,644
Fruit	1,482,865	74,438
Citrus fruit	5,862,842	316,200
Grapes	1,001,080	78,947
Other deciduous fruit	143,093	1,545
Pineapples	645,755	51,449
Vegetables	2,804,657	55,374
Coffee and spices	708,035	105,854
Canned goods	302,782	8,253
Assorted fruits and vegetables	272,643	13,632
Nuts	224,468	21,630
Eggs	4,640	2,784
Milk	1,838	110
Butter and cheese	2,165	866
Confectionery	118,785	17,818
Miscellaneous	58,251	4,923
Total	14,534,710	$887,876

It is interesting to note that the condemned food in New York City during 1917 contained nutrients sufficient to have fed for the whole year one of Uncle Sam's regiments of 3775 men.

It will be interesting and profitable to go into the details of some of the cases reported by this Terminal Squad. For instance, on June 28 and 29, 1917, three cars of potatoes from Florida arrived at Pier 28, North River, in bad condition. They were ordered overhauled, and because the commission-merchant consignee refused to overhaul promptly all of one car had to be destroyed. These potatoes were packed while wet into double-headed barrels, insufficiently ventilated, and therefore heated while in transit. Not only did the shipper lose the barrels which were destroyed, but he had to take a price lower than the market for subsequent perfectly good shipments, because buyers were afraid of his line, as he advised me in a letter.

We should not expect this kind of loss in canned goods, but 6500 pounds (164 cans) out of a carload of tomato paste, packed in 5-gallon cans, was found on November 10, at Pier 28, in bad condition. These cans had been placed in the car without being crated and without braces or boards to prevent shocks in shipment. The consequence was that the cans in the lower tiers parted at the joints from the weight on them, and a large number of the others were punctured as a result of improper stowing while in shipment.

Marrons, or so-called Italians chestnuts, are now being shipped in large numbers from Spain and Portugal. There is a large accumulation of these nuts awaiting transportation, and the United States appears to be the chief, if not the only, market. The ships are ill-ventilated, when any ships at all are available, and run slowly, because of the high price of coal. It has been found necessary to embargo almost all shipments received this season because they are heated, and the total condemnations amount up to date to more than 2,000,000 pounds. This is one of the classes of waste which it is almost impossible to prevent under present conditions, because of disturbances produced by the war. The same thing is true of a recent condemnation of some 19,000 barrels of Spanish grapes.

An instance of actual conservation is involved in the case of 1300 boxes of lemons last June. In this instance the owner was prevailed upon to overhaul, making an actual reduction of his loss by $281, while an analogous instance is that of 29 barrels of potatoes received in July which were turned over to the city salvage kitchen, and the 24 barrels of potatoes recovered sold at a price of one cent per pound. Another instance on the same day showed that the spoilage of 87 bags of potatoes out of a lot of 250 was due to the fact that early potatoes were shipped in burlap bags, when they should have been shipped in ventilated barrels. This was the farmer's fault; and another case where the farmer made a mistake occurred the following month, in which a shipment of 200 barrels from Virginia was left after digging exposed to rain, followed by sun, packed when thus heated, and then were allowed to stand on the loading tracks for several days, awaiting a track-buyer.

A loss due to poor judgment of the best marketing point is exemplified by the large shipments of cucumbers to the New York market during the week ending July 1, resulting in a market glut. After sending about 10,000 pounds to city institutions, 100,000 pounds additional were dumped upon the Jersey meadows because there was no sale for them at any price and they had become or were becoming unsound.

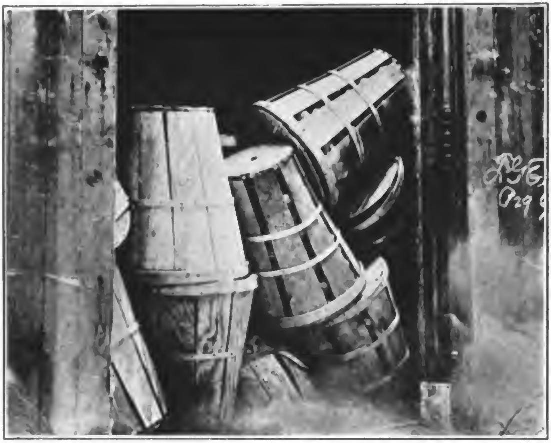
During the week beginning August 24 there arrived at the Spanish Line Pier in Brooklyn 125,000 pounds of onions, partly unsound, and the consignees refused to overhaul them and pay the duty. Forty-odd thousand pounds could have been saved by volunteer workers but for the fact that the Federal Government refused to waive demand for duty on the sound portions.

For the past year there has been an excellent market for beans at high prices, the result being that large shipments have come in from South America, India, Manchuria, etc. Some of these beans, particularly those from South America, are infested with eggs and larvæ of certain weevils. On storage these develop, and the infestation spreads from the original proportion of three or four per cent. of the lot to fifty per cent. and more. These flies are impartial in their tastes and will infest other lots of beans in the same warehouses, whether of domestic or foreign origin. The losses within the last twelve months from this cause run to millions of pounds, and there is in addition the grave danger of introducing such dangerous pests into our own fields. All this can be prevented by prompt fumigation of the beans on receipt. No government agencies up to this time have had laws to proceed under to compel such fumigation, although the city requires that they be fumigated and made sound before actually entering trade.

Typical instances of this sort could be multiplied. It will be noted that almost everything that I have quoted is preventable. It is particularly desirable, however, to call attention to the importance of suitable and strong containers, the failure to use which has caused so large a proportion of loss. This feature, as well as the importance of proper stowing in the cars, is shown by Figs. 2 to 11, which likewise illustrate the saving of space, rolling stock, and motive power which may be effected by proper stowing and bracing of the load, and by using the full capacity of the car. The descriptions under each plate tell the story well.

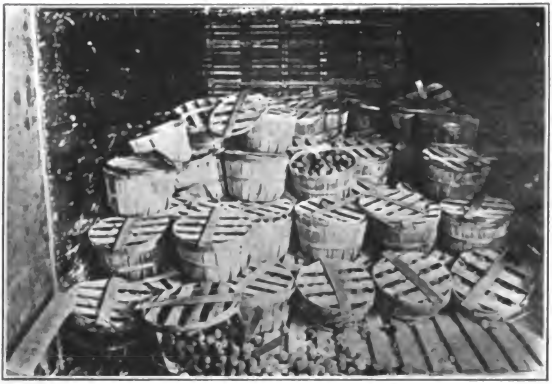
Another most important cause of loss is the failure to properly grade and pack. Only in a few sections is this thoroughly understood by the producer. Farmers habitually load potatoes "field run," "plate" barrels of apples (putting the "baby" sizes in the middle), load specked goods with sound and the like. Failure

FIG. 2.



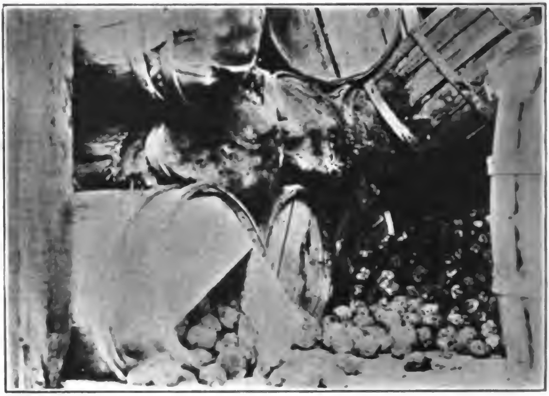
A poorly packed car of cucumbers on opening. Note crushed baskets. (New York City Department of Health.)

FIG. 3.



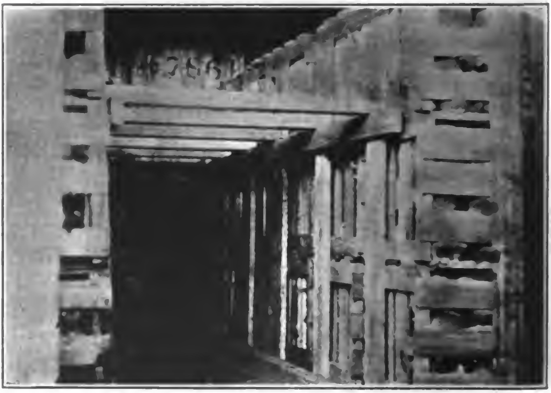
Peach baskets crushed because no shelving was provided in car to keep weight off bottom tiers. (U. S. Department of Agriculture, Office Markets.)

FIG. 4.



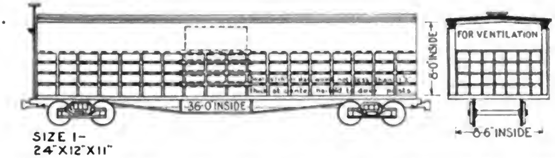
Potatoes in cloth-top barrels stored in car three high, *on bilge.* They should be stored on ends. The stupidity of this method of loading is apparent. (U. S. Department of Agriculture, Office Markets.)

FIG. 5.



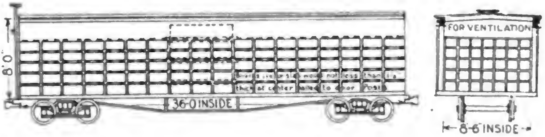
Crates of cabbage properly loaded and braced in car. (U. S. Department of Agriculture, Office Markets.)

FIG. 6.



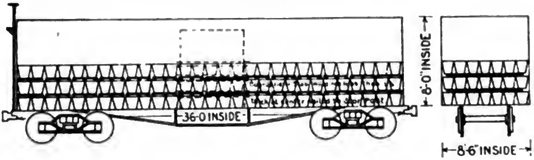
Fresh tomatoes in crates. Ordinary method of loading. Five hundred crates per car, weight 20,000 pounds. Note waste of space.

FIG. 7.



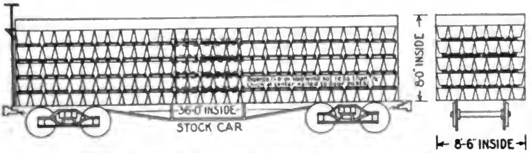
Fresh tomatoes in crates. Approved method of loading by adding an additional layer of crates, increasing capacity of car by twenty-five per cent.

FIG. 8.



Fresh tomatoes in hampers. Average load, 609 hampers (27,000 pounds). Wastes forty per cent. cubical capacity of car.

FIG. 9.

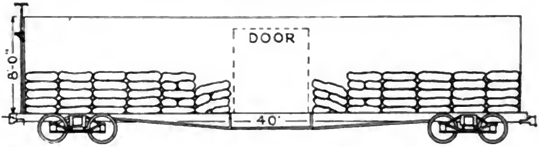


Approved method of loading fresh tomatoes in hampers—1015 baskets (46,000 pounds), utilizing full cubical capacity of car. The small additional labor and lumber costs involved will increase carrying capacity of rolling stock by two-thirds, or an equivalent of sixty-seven per cent. greater number of cars, and ending waste from tomatoes rotting on ground through lack of shipping capacity.

NOTE.—I am indebted to the Pennsylvania Railroad Company for permission to reproduce Figs. 6 to 11.

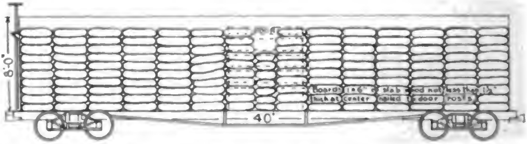
to separate the different grades not only brings down the price of the best, but raises little, if any, the price of the worst. Due attention to packing and grading stops waste, attracts purchasers, enables a systematic use of unmarketable material, and always assures a market through making a reputation for the goods concerned. For instance, only strict attention to grading and packing enables the Western fruit grower to ship to Eastern markets; conversely, its absence prevents goods produced in the East, as a rule, from seriously competing with the attractive Western stock.

FIG. 10.



Loading of sugar according to old selling standards. Car load unit, 400 bags (40,800 pounds). Note extreme waste of car space. This illustrates one of the old bad trade customs which should not have waited for war conditions to be broken up.

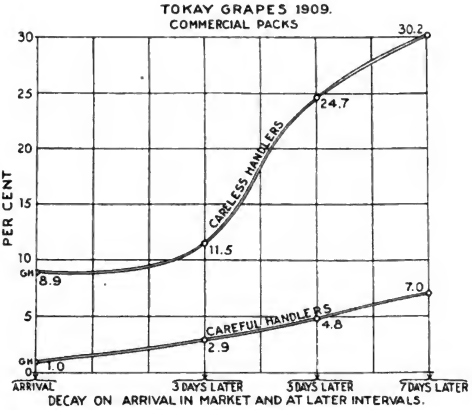
FIG. 11.


8'-0"
Boards 1x6" or slab wood not less than 1½"
thick at center nailed to door posts
40'

Approved method of loading cars with sugar—1000 bags (102,000 pounds), utilizing full cubical and weight-carrying capacity of car.

In the retailer's end, at least in large cities, the waste is small, in the individual case, but probably very large in the aggregate. Neglect of the stock, and overbuying, are responsible, without doubt, for a considerable proportion of it. Sound open stock is contaminated by failure to remove unsound stuff, or by rats or other vermin. There is a certain amount of loss in canned goods, due to the fact that dented cans or those with discolored labels are less salable (although the contents are unaffected) than those with a nice appearance, and are therefore destroyed. In certain poor sections of the large cities food is sold in very small portions, such as a quarter of a loaf of bread; the cut unsold portion which remains overnight is unsalable. Early in the season or in times of frosty weather the retailer receives potatoes in bad condition, necessitating sorting by him. There is considerable loss in fish because of poor icing and a failure to utilize the heads, napes, and fins for chowder or flavoring purposes. Consumers' demands, however, are probably responsible for the largest loss here. Fancies of customers are responsible for failure to utilize a great deal of material, and the waste of time and money due to the demand for delivery service is of paramount importance.

FIG. 12.



Showing difference between results of careful and careless commercial packs of Tokay grapes. (U. S. Department of Agriculture, Office Markets.)

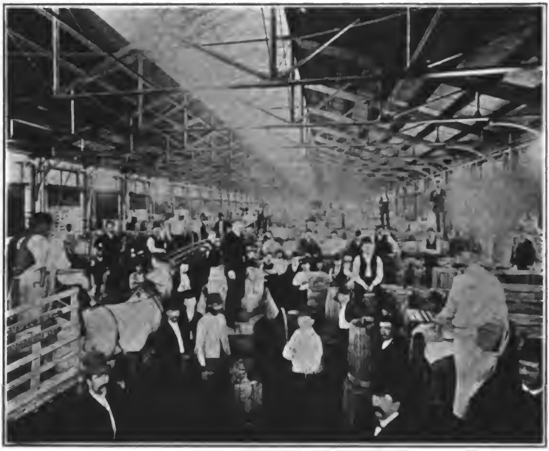
The largest wastes of all, however, appear to occur in the utilization of food in the kitchen, whether this be in the private family or the restaurant. A short survey made in New York under my direction in July, 1917, of the amount of food thrown into the garbage pail shows how much we actually throw away. Garbage varies greatly in its composition, and the amount of waste will vary with the race of the consumer, with the actual price of foods, and with the scale of living. Even giving all due allowance to these limitations, this survey is very illuminating. It was made by accompanying the garbage collectors on their rounds, sorting out, estimating, and listing the kind and amount of food found in the garbage cans. Some 27 per cent. of material was found which was apparently fit for use when thrown into the garbage pail, giving an average value per pound of the whole of 2½ cents, or $50 per ton load. If the amount and value of this be discounted 20 per cent., we reach the huge sum of $15,945,520, or a value sufficient to buy food for 136,520 people for a year. Of this waste, about one-third is bread and about half as much is meat, the rest being vegetables, beans, etc. The waste is, of course, greatest in well-to-do sections, and there is little waste by the poorer families, in whose case it consists mostly of vegetable tops and trimmings which the French would use. The redeemable values vary from 1.4 cents per pound in the poorer sections of the city to 3.5 cents in the more well-to-do. The medium wage-earner, the small business man, or the rich man appears to be the worst offender.

I have mentioned bread above. On the basis calculated, the waste for the city in a year would be about 60,000,000 pounds of bread, equivalent to 964,287 bushels of wheat or 0.18 bushel each, which if applied to the whole United States, would give us a waste of 19,800,000 bushels per annum, and this applied to the eight months from January to September, 1918, would make quite a hole in the 90,000,000 bushels which the United States Food Administration tells us we must send to our Allies in that period.

In the hotel and restaurant kitchens and dining-rooms the efforts made to attain efficiency in operation have been greatly promoted by the high cost of food during the past three years. This, however, does not apply to the usual run of "American plan" hotels, in which the absolute wastes of food are nothing else than shocking. In these places the amount of uneaten food is probably quite as large as, or larger than, that which is eaten, and, inasmuch as when once served there is no way of knowing whether it has been touched by the patron, there is no means of redeeming it, and it must all go to the garbage pail. Real wastes found by actual inquiry have been found to be most largely in succulents and green foods; the outside of the heads and the tops and trimmings of such stuff as radishes, beets, and asparagus are very seldom utilized, although in a few places they are used for salads or soup stock. There is little or no waste in meats and fish, except for the returned portions.

At the period of investigation some six months ago a good deal of butter was used for frying purposes. It is to be expected and hoped this is now substituted by cheaper fats. Without rather exhaustive work, it would be difficult to ascertain the exact amount of real waste in restaurants. The opinion of one steward, who acknowledged that he had nothing to base it upon, was that unavoidable wastes were 15 per cent. This furnishes at least something to hang judgment on.

FIG 13.



Pier 29, Pennsylvania Railroad, New York City, showing crowded condition during shipping season. (New York City Department of Health.)

One sin of which some hotels are unquestionably guilty is the burning of garbage as the easiest way to get rid of it. It should, of course, be utilized for its fat and feeding value for animals. The hotels apparently have much to answer for to the Food Administration, if we are to credit the newspaper reports which indeed are confirmed by the observation of all of us who have occasion to deal with them. Their offences are based on a desire to get and keep business. Here again the customer is responsible, and we have to condemn the hotel proprietors possibly for nothing else except lack of "backbone" and a failure to get together among themselves so as to eliminate unfair competition.[1] Our own investigations in New York last summer showed that there are entirely too many side orders and side dishes served, the portions were unnecessarily large, there was a great waste of the expensive and necessary milk, butter, cream, and eggs in the making of fancy pastry, and at that time there was an enormous waste of bread, which was sold, after becoming one day old, for hog and chicken feed. The latter practice has now practically been stopped, I believe.

The more intangible losses in the home kitchens due to unbalanced rations, to poor cooking, and to the lack of a proper system in the kitchen are probably very much larger than the wastes in garbage, but there is no means of accurately estimating them at hand; the United States Department of Agriculture's Division of Home Economics places them at a money value of $700,000,000.

From a war-time standpoint there is an enormous waste of foods predicated by the mere existence of non-essential food industries. It can hardly be said that the great number of candy shops serve any other urgent economic need than that of an occasional physician. Soda-water and other soft-drink stands absorb, in the aggregate, an enormous amount of food without, so far as we can see, making any notable contribution to the national nutrition.

Condiments have a recognized value in the dietary, but it is open to question whether their use is not excessive, and certainly when their preparation involves the consumption of materials which can just as well be used whole, their free manufacture should be questioned. Thus there are more than a ton of eggs a day used in New York City for making mayonnaise dressing. It is desirable to avoid drastic and sudden interference with non-essential industries, but we cannot escape the conclusion that their output should be decreased gradually to a point where there is not serious interference with those industries with which we cannot dispense.

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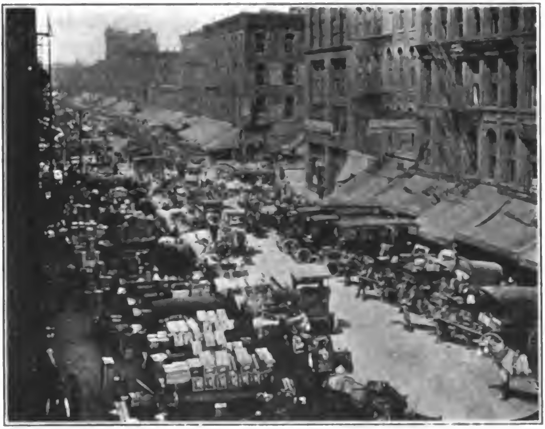
[1] Since this was written the efforts of the Hotel Division of the U. S. Food Administration appear to have been productive of such improvement as to remove most of the reason for criticism.

It is stated that the Food Administration desires the passage of a bill extending its powers so that it may enforce its orders on places of public entertainment and in other quarters where enforcement cannot now be had. Not only should such power be given at once, but if the power does not now exist to punish both public and private consumers for wilful wastes, that power should be conferred. It has been freely used in England and appears to have been of value there.

FIG. 14.



South Water Street, Chicago, at a busy hour. This shows waste in double hauling from terminal to warehouse and then to retailer. Every large city can duplicate this scene. (U. S. Department of Agriculture, Office Markets.)

Losses in foodstuffs produced by a defective economic system of marketing are difficult to estimate accurately. I have already suggested certain of those which have both physical and economic aspects, such as careless packing, poor grading, delays in transit, etc. Those which may be said to be of a purely economic nature are in part as follows:[2]

(*a*) In marketing at country points: Lack of knowledge of market conditions and of prices, on the part of farmers; an unnecessary number of local buyers; abuse of monopoly power when there is only one buyer and of price agreements when there are several buyers; poor business management; poor roads.

(*b*) In the wholesale trades: Opportunity for sharp practice and fraud; lack of adequate inspection system; lack of adequate price-quotations system; insufficient means of procuring and disseminating information on crop and market conditions and crop movements; lack of uniformity of methods, customs, grades, packages, etc., as between different markets; control of auction companies by cliques, etc.

(*c*) In the transportation end: Ill-adjustment of rates between localities and between commodities; lack of uniformity in making adjustments of claims for damage; unfair icing charges, etc.

(*d*) In the retail system (which is, according to Weld, the most expensive element in the marketing system): Dishonesty in weights and misrepresentation as to quality; overstocking; too little credit; delay in payment for goods bought from wholesalers; unnecessary duplication of delivery and other equipment and services.

The retailer, likewise, is not to be charged with all the excessive costs in his business. The desire of consumers for expensive service, including prompt delivery of small orders, is one of the most fruitful causes of waste motion in food distribution.

When we come to consider the question of remedies, we must bear in mind that the deficiencies, physical and economic, are both very numerous and of great diversity, and that we have had time here to consider only a small part of them. There is no simple panacea which can be applied, nor will any single revolutionary process help us. Weld suggests that the economic, and probably a large part of the physical, wastes may be remedied broadly under four classifications, to wit: First, coöperation among farmers and among consumers; second, associative effort on the part of middlemen; third, education; fourth, governmental regulation. For losses at the farm, educational means concentrating on grading and packing are of particular importance.

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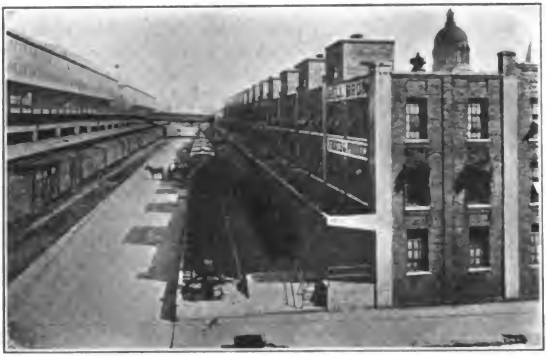
[2] L. D. H. Weld, "The Marketing of Farm Products," ch. xxi.

Farm labor is scarce, and to this condition the new Labor Supply Bureau of the Federal Government will afford at least a certain measure of relief. For losses in transportation, that coördination of the railways which ought to follow Federal operation will greatly reduce difficulties. Two points are of particular interest here; namely, that city terminals now used to only partial capacity by one or two systems will be available to all railroads, resulting in prompter deliveries and in shorter hauls by receivers, and that we should expect, likewise, to see a cessation of the practice of holding loaded cars for a rise in the market or for use as warehouses.

FIG. 15.



Wholesalers' stores owned by railroad, and goods unloaded at rear. Saves unnecessary handling and carting. (U. S. Department of Agriculture, Office Markets.)

For goods which have actually become partly unsound a certain amount of salvage can be had by turning over to associations of volunteer workers in the large cities, for the application of preservative processes, such as canning, or who may sell direct at a reduced price to consumers. Labor costs in salvaging are, in this way, eliminated, and the goods should cost such volunteer agencies nothing. Another method of utilizing goods thus abandoned by the consignees would be through turning them over to those parts of the city government charged with the buying and selling of food or to public or private charities. In applying such methods of salvage to imported foods, the matter of claims of the Treasury Department for duty must not be overlooked, and on goods not sold for profit the duty should be remitted.

Little which has not already been said can be named now as to a remedy for the defects in retailing. Most of us have our own ideas about this end of the business, and if some of them were applied by each one of us in our sphere of activity as customers we should unquestionably make some progress. But most people are quite willing to let somebody else apply such remedies.

There is one method of conservation of food materials which deserves a paragraph to itself. This is the dehydration of foods, so extensively practised before and since the war with Germany. There are apparently more than two thousand of such establishments now in operation in that country. The simple process is one which was extensively used on a household scale all over the world before the great development of canning within the past fifty years and which is still practised in remote districts. There is, therefore, no question as to its practical character. It consists merely in the reducing of the sound fruits or vegetables to suitably sized pieces and the subjecting of this material to hot air, combined, for the most satisfactory products, with an atmosphere of moderate humidity.

In connection with a patriotic woman of New York City, the Health Department of that city did much work last summer with a view to developing a practical method for dehydration. The results showed that the cost was reasonable, the product left little to be desired, and when reconstituted was for most purposes fully the equal of fresh material. Speaking broadly, the advantages to be derived from a development of dehydration in the United States are as follows:

(*a*) The utilization of surplus now remaining in growing districts, which, for one reason or another, cannot be shipped in fresh condition, such reasons being chiefly too rapid ripening for the market to absorb, difficulty of obtaining labor, and unfavorable weather conditions preventing shipment.

(*b*) A very considerable development of the consumption of vegetables in America, thus relieving the present defective character of our dietary in this respect as compared with that of European nations.

(*c*) Consequent increase in production of vegetables.

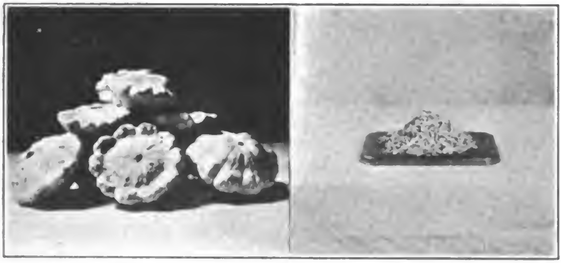
(*d*) And proceeding from these, a lesser consumption of stable foods, such as grain, meats, etc.

(*e*) A possible lessening of the demands on the railroads for weight and car space to haul fresh vegetables, which contain from 75 to 95 per cent. of water.

(*f*) Finally, the enabling of purchase by the poor in the cities of vegetables the year round.

The chief difficulty in the way of the growth of the industry is the fact that there is at this time no market in civilian life ready to take its products. This need not, however, deter persons who may be thinking of developing it because, for any amount which can be produced within the next two or three years, the American

FIG. 16.



Dehydration of vegetables. The small pile shows the size of the large pile of squash after drying. The same thing happens with all other vegetables. Note great saving of space.

and allied armies will furnish more demand than can be possibly supplied. The French Army uses about one-half pound a day of this material per man, the Germans even more, both of them in the form of soups and stews. Certain elements in immigrant American life make of such prepared dishes a large part of their dietary, and no great educational campaign would be necessary to induce a considerable buying movement among these people. An important " talking point " to encourage use is that the preparation of the vegetables is all done before dehydration, thus relieving the housewife of that tedious and none too pleasant job.

It is further to be said that during the past season farmers and truck growers did their whole duty in increased production, particularly of perishables, a comparatively large part of which consumers were unable to utilize, and there was much complaint of these crops going to waste, throwing unwarranted loss on producers. It is the simple duty of the rest of the country to supplement these agricultural efforts by the establishment of small low-cost dehydrating units near points of production. They can be most profitably located in combination with canneries, mills, or any other manufacturing units furnishing buildings and power.

Time does not allow of treating in detail certain most important changes having at once economic, agricultural, manufacturing, and dietary factors. C. L. Alsberg has well called attention to these: Quoting Farmer's Bulletin No. 629, he notes the fact that only 3.4 per cent. of our corn crop, $^{9}/_{10}$ per cent. of our oats, and $^{7}/_{10}$ per cent. of the barley goes into human food—a purpose for which they are all largely used in other countries; that the optimum use of feeding-stuffs has been made by hogs at 150 pounds weight and by beef cattle at 6 months of age, and they should then be killed; that 27½ per cent. of the milk supply goes into skim-milk (our cheapest source of animal protein), which is now fed to animals; that too much foodstuffs goes into the arts, such as for starch, sizing, foundry-cores, etc., and, finally, that we utilize nothing like our capacity in producing various oil-seeds which would prevent our suffering from that fat-hunger which, rather than protein-hunger, has produced the greatest hardship in Germany. The whole subject is one of such infinite variety that only single aspects of it can be touched upon within the limit of one paper.

PHYSICS OF THE AIR.*

BY

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CHAPTER XIII.

FOGS AND CLOUDS.

THE deposition of dew, the forming of hoar-frost, and the sweating of ice pitchers, all examples of surface condensation, show that atmospheric moisture promptly condenses upon any object whose temperature is below the dew-point. Similarly, volume condensation takes place in the form of a fog or cloud of innumerable droplets, or ice spicules, throughout the body of ordinary air whenever by expansion or otherwise it is sufficiently cooled. But this is not equally true of all air. Thus, while the first considerable rapid expansion, and therefore decided volume cooling, of humid air in a receiver, if recently admitted unfiltered, is quite certain to produce a miniature cloud, subsequent expansions of the same air produce fewer and fewer such particles. If the old air is removed and unfiltered fresh air admitted, the condensations again occur as before; but if the fresh air enters through an efficient filter, such as a plug of cotton wool a few centimetres long, condensation remains as difficult as in the exhausted air. The admission, however, of a little smoke restores to the exhausted and confers upon the filtered air full powers of condensation.

Obviously, then, cloud droplets form about nuclei that cannot easily pass through mechanical filters of fine texture, and microscopic examinations of the residue left on the evaporation of these droplets have shown the nuclei to consist in large measure of dust particles, both mineral and organic. Hygroscopic gases, such as the oxides of sulphur and of nitrogen, may also act as condensation nuclei, but ordinarily there is abundant dust in the atmosphere (thousands of particles per cubic centimetre) to provide for all precipitation. It is often urged that free electrons in the air also act as nuclei about which water vapor condenses, but, as this type of condensation requires about a fourfold supersaturation, its occurrence in the open seems extremely improbable.

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* Continued from page 538, vol. 185, April, 1918.

As stated, volume condensation may be induced in the atmosphere by any cooling process: whether by radiation, as on clear nights; mixing warmer with colder masses of air; movement of relatively warm air over cold surfaces, as in the case of winter south winds (northern hemisphere); or expansion, owing either to convection or barometric depression. But the cooling process has much to do with determining the extent of the condensation, the kind and amount of precipitation from it, and its general appearance, according to which, chiefly, it is classified.

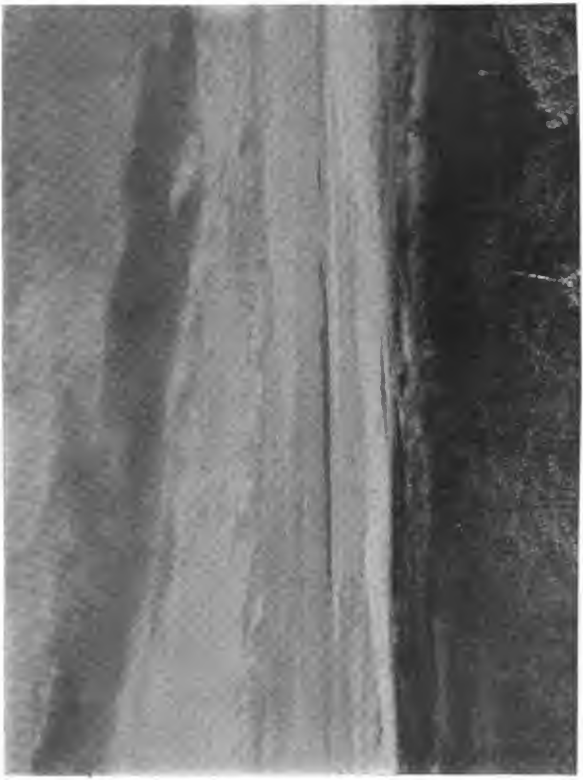
Distinction Between Fog and Cloud.—Volume condensation is divided primarily into fog and cloud, but a sharp distinction between them that would enable one always to say which is which is not possible. In general, however, a fog differs from a cloud only in its location. Both are owing, as explained, to the cooling of the atmosphere to a temperature below its dew-point, but in the case of the cloud this cooling usually results from vertical convection, and hence the cloud is nearly always separated from the earth, except on mountain tops. Fog, on the other hand, is induced by relatively low temperatures at and near the surface, and commonly itself extends quite to the surface, at least during the stage of its development. In short, fog consists of water droplets or ice spicules condensed from and floating in the air near the surface; cloud, of water droplets or ice spicules condensed from and floating in the air well above the surface. Fog is a cloud on the earth; cloud a fog in the sky.

FOGS.

According to the conditions under which they are formed, fogs may be divided into two general classes—radiation fogs and advection fogs.

Radiation Fog.—Fog is likely to form along rivers and creeks and even in cleared mountain valleys during any still, cloudless night of summer and, especially, autumn. In the course of a calm warm day much water is evaporated into the lower atmosphere of such regions, where in large part it remains as long as there are no winds. Hence this air, because it is humid, and the adjacent surface of the earth lose much heat during the

FIG. 61.



Radiation fog, Loudoun Valley, Va. (A. J. Weed, photo.)

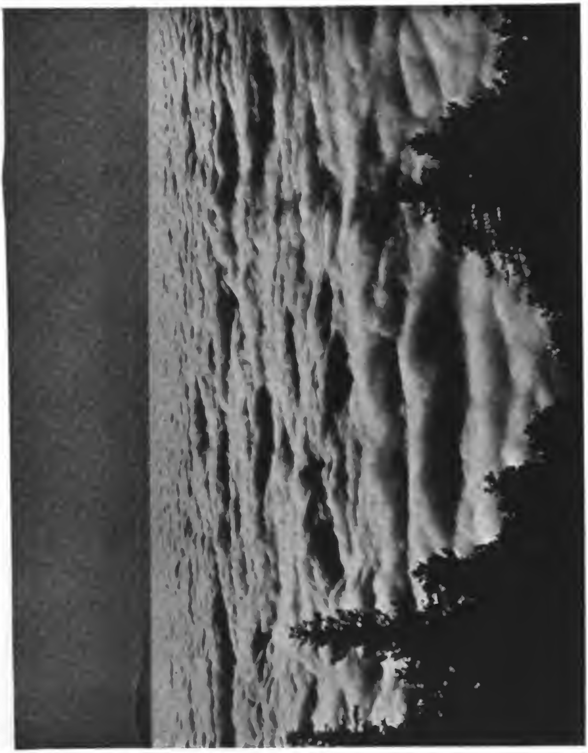
night by radiation to the clear sky. In many cases they cool in the end to a temperature below the dew-point, and thus induce a greater or less volume condensation on the always-present dust motes that results in a correspondingly dense fog (Fig. 61). Such fog, however, is not likely to occur during cloudy nights, because the air seldom then cools sufficiently, nor during high winds, since they dissipate the humidity and also through turbulence prevent the formation of excessively cold aerial lakes.

The distinctive factor in the formation of this type of fog is the free radiation of the ground and the lower air by which the latter is sufficiently cooled to induce condensation. Hence fogs formed in this manner are properly termed "radiation fogs," sometimes also called "land fogs" and "summer fogs."

Advection Fog.—Whenever warm, humid air drifts over a cold surface its temperature is reduced throughout the lower turbulent layers by conduction to that surface and by mixture with remaining portions of the previous cold air and a correspondingly dense fog produced. Hence fog often occurs, during winter, in the front portion of a weak cyclone; also whenever air drifts from warm water to cold—from the Gulf Stream, for instance, to the Labrador Current; and wherever gentle ocean winds blow over snow-covered land—circumstances that justify the terms "winter fog" and "sea fog" (drifting on shore in places, and even some distance inland, Fig. 62). Similarly, a cold wind drifting or spreading under and through a body of warm, humid air also produces a fog, though usually a comparatively light one. This explains the fog that frequently forms, during winter, along the front of a "high," and the thin fog that occasionally is seen over lakes on frosty autumn mornings, when the water appears to be steaming—actually evaporating into air already saturated and thus inducing condensation. It also explains the frequent occurrence of "frost smoke" on polar seas.

If the wind is strong the turbulence extends through a comparatively deep layer. Hence in the case of warm air drifting over a cold surface if the movement is rapid the total duration of contact between any portion of the air and that surface is likely to be so brief that but little cooling can take place and no fog be formed. Similarly, it usually also happens that fog does not form when the cold wind blowing over a warm, humid region is even moderately strong. Here the turbulence mixes the ex-

FIG. 62.



Advection fog, seen from Mount Willson, Cal. (F. Ellerman, photo.)

cessive humidity near the surface through so large a volume that saturation commonly is not produced, nor, therefore, any trace of fog.

From the above it appears that all fogs that result from the drifting of warm, humid air over cold surfaces, as also those that are produced by the flow of cold air over warm, humid regions, are but effects of temperature changes induced by the horizontal transportation of air; hence the proposed general name, "advection fog." The term advection is preferred to convection because the latter is practically restricted, in meteorological usage, to a change of level, whereas in the case under consideration only horizontal movements are concerned. The contradistinction, therefore, between "advection fog" and "convection cloud" is obvious, and, presumably, worth while.

CLOUDS.

The cooling of the atmosphere by which cloud condensation is induced is most frequently, perhaps, produced by vertical convection, either thermal or forced; often, presumably, by the mixing of winds of different temperatures; occasionally by pressure changes, elevation remaining the same; occasionally, also, by radiation; and rarely, in the case of very thin clouds, by diffusion and conduction.

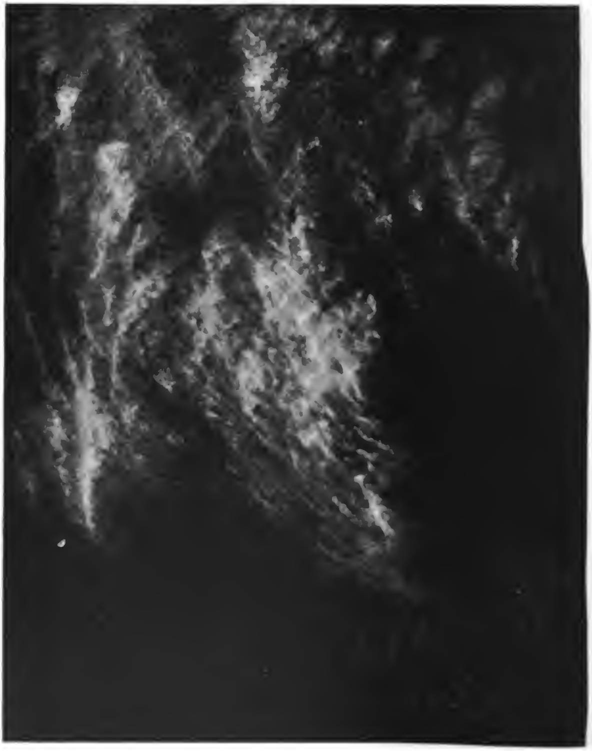
Radiation, though productive of many fogs, is excluded from the list of principal cloud-forming processes for the reason that, as explained elsewhere, any mass of free air that cools in position, as it must whenever its radiation exceeds its absorption, immediately gains in density and falls to a lower level where, when equilibrium is reached, it actually is *warmer* than it was before the cooling began, and its relative humidity therefore lower. Hence it seems that radiation could produce clouds only when equally active, or nearly so, over an extensive layer of practically saturated air. If radiation is unequally distributed it tends to evaporate clouds rather than produce them.

Classification.—It is not practical, however desirable, to classify clouds according to their causes, as in the case of fogs, for it often happens that the exact cause is not obvious. Hence other bases of classification have been adopted, especially form or appearance, activity, and position. Most, but not all, clouds belong to one or other of the four distinct types, *cirrus*, *stratus*,

FIG. 63.

Cirrus. (F. Ellerman, photo.)

FIG. 64.



Cirrus. (F. Ellerman, photo.)

cumulus, nimbus, including their alto, fracto, and combination forms; alto-stratus, alto-cumulus; fracto-stratus, fracto-cumulus, fracto-nimbus; cirro-stratus, cirro-cumulus, strato-cumulus, cumulo-nimbus.

Cirrus (Ci.).—The name cirrus, literally a curl or ringlet, has been given to those fibrous white clouds that resemble great wisps of hair (mares' tails), giant curling plumes (feather clouds), tangled skeins, and various other things (Figs. 63 and 64). These are the highest, often 10 to 12 kilometres above the earth in middle latitudes and still higher in tropical regions, the most tenuous, and among the most familiar of all clouds.

Since cirri usually run far ahead of the rainy portions of cyclonic areas, and grow denser as the storm approaches, it is obvious that they frequently result from cyclonic convections that extend nearly or quite to the stratosphere, where, and for some distance below which, the rising air is carried forward much faster than the storm centre. But they also are fairly common in the midst of "highs," due, presumably, to a mechanical or bodily lifting of the upper air of these regions, or overrunning of air in the general circulation, and, consequently, dynamical cooling not only of the stratosphere, as abundantly shown by the records of sounding balloons, but also of the topmost portion of the troposphere where cirri usually form.

It has been suggested that cirri often are caused by cooling in place by radiation, but, as already explained, this appears to be improbable for clouds so broken and discontinuous. On the contrary, however, it seems likely that through free radiation and cooling at night they often sink to lower levels, get *warmer,* and evaporate. Thermal and mechanical convection, therefore, the first prevailing in tropical regions, the second, presumably, in extratropical, appear to be the only abundant causes of cirri.

The excessively low temperatures at which cirri are formed, generally −30° C. to −50° C., necessitate their being tenuous (at such temperatures there is but little water vapor to condense) and practically insure (exceptions have been reported[81]) that they shall consist of ice needles. Their fibrous and feathery structures may perhaps be explained as follows: Since diffusion is a very slow process, it follows that humidity is carried into the upper atmosphere mainly by vertical convection, and, as this

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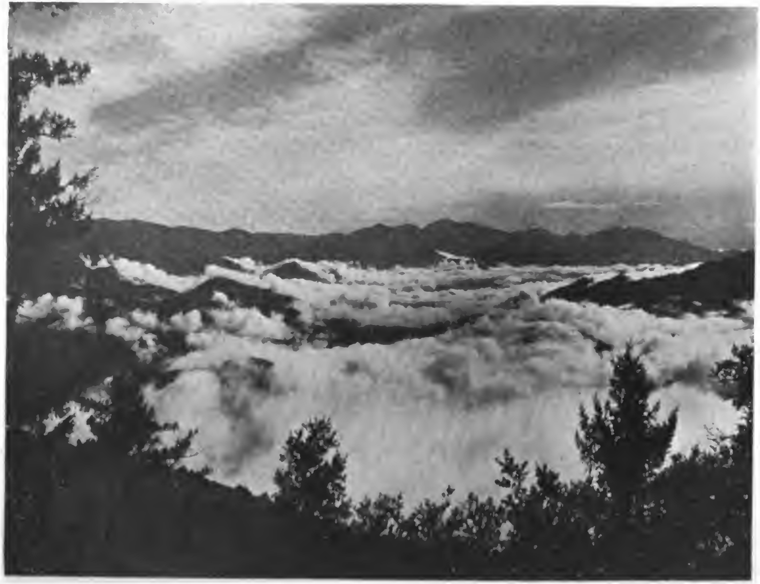
[81] Simpson, *Qr. Jr. Roy. Meteorol. Soc.*, **38** (1912), p. 291.

FIG. 65.



Cirro-stratus, and advection fog, seen from Mount Wilson, Cal. (F. Ellerman, photo.)

often occurs sporadically, it appears that through the increase of winds with elevation, the rising and generally humid air is likely to be drawn out into long threads and bands, and to float away in filaments at the convective limit, just as during the early hours of calm autumn mornings chimney smoke in mountain valleys often is drawn out into streaks and ribbons at or near the inversion level.

Any cloud, therefore, produced in this fibrously humid air obviously itself must have the same general structure—a common structure of cirrus clouds. Through local convection, however, and abrupt changes in velocity at the level of these clouds the air currents to which they are due presumably often are deflected into curves of changing radii. Hence, perhaps, the curved or plumed cirrus.

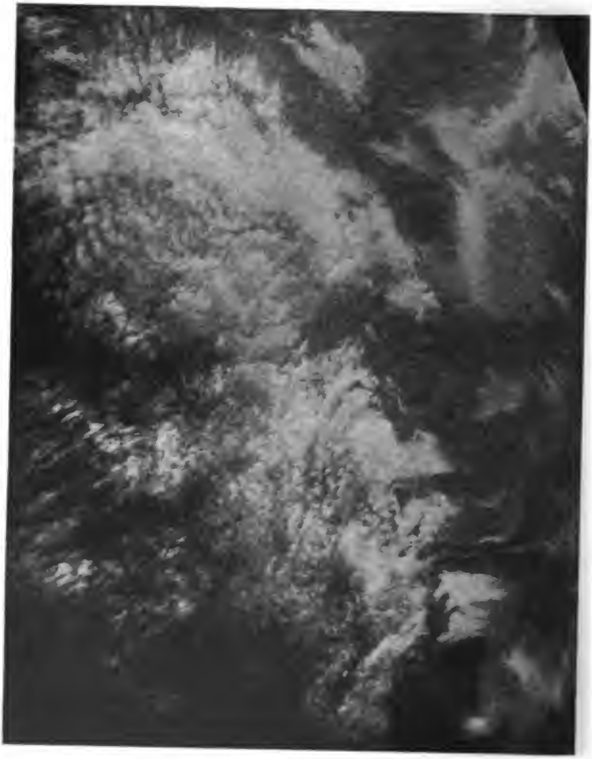
Cirro-stratus (Ci.-St.).—When cirrus clouds thicken, as they usually do on the approach of a cyclonic storm, they gradually merge into a broad cloud layer, having the appearance of a more or less continuous white veil of uneven and often fibrous texture (Fig. 65), to which the name cirro-stratus has been given. Its altitude is nearly that of the cirrus, of which indeed it is only a dense and extensive form, though its under surface is not so high. Like its forerunner, the thinner cirrus, it also consists of ice crystals, as is evident from the various types of halos it forms about the sun and moon.

The origin of these clouds is substantially the same as that of the cirrus; that is, convection, which in turn may be caused by general expansion of the air below or by convergence of winds, such as occurs in the cyclone. Frequently, as explained above, the cirro-stratus is only the higher and swifter portion of the cyclonic cloud system, the result of forced convection to great altitudes.

Cirro-cumulus (Ci.-Cu.).—Cirro-cumuli are small, fleecy cumulus clouds, generally 6 to 7 kilometres above the surface; that is, in the lower cirrus region. They usually occur in large numbers, producing an effect sometimes described as "curdled sky"; frequently, also, in groups and rows that remind one of the patterns (not the scales) on the backs of mackerel. Hence the expression "mackerel-back sky," commonly abbreviated to "mackerel sky" (Fig. 66).

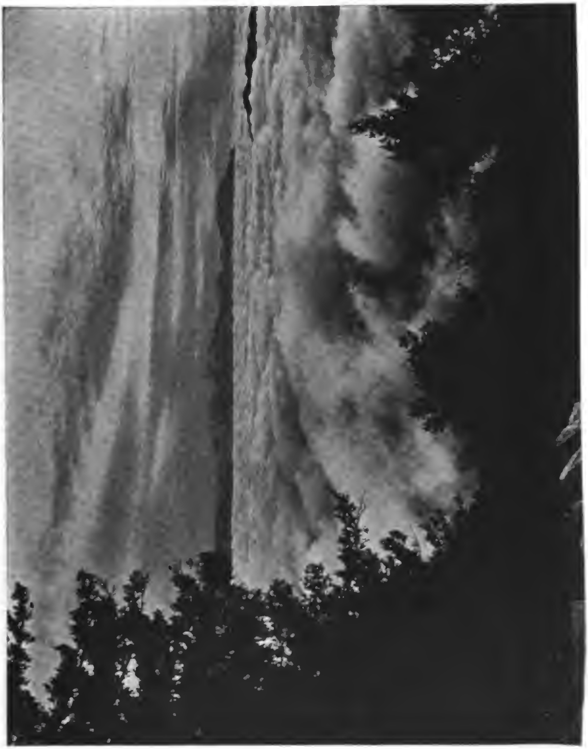
Their origin obviously is due chiefly to a single cause—local

FIG. 66.



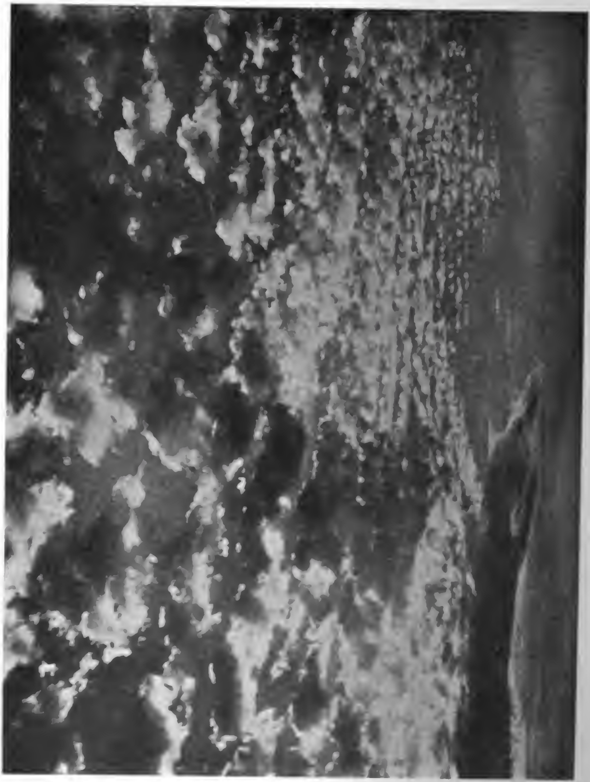
Cirro-cumuli. (F. Ellerman, photo.)

FIG. 67.



Alto-stratus, and advection fog, seen from Mount Wilson, Cal. (F. Ellerman, photo.)

FIG. 68.



Alto-cumulus. (A. J. Weed, photo.)

vertical convection, induced by unequal local heating. To each convective rise of the air there evidently must be an equivalent descent, and if the heating maxima are numerous the minima between must also be numerous, thus producing many rising currents, each with its small cumulus, surrounded by descending air and relatively clear sky.

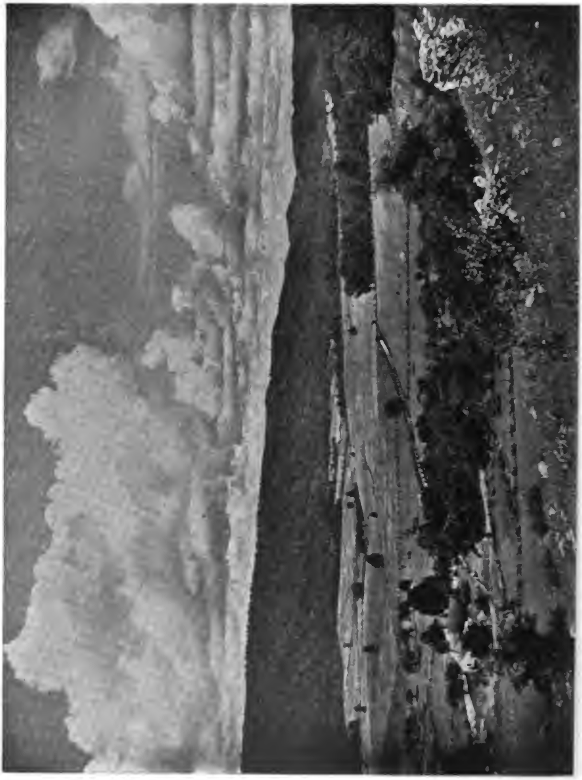
Alto-stratus (A.-St.).—The alto-stratus is a thick, grayish cloud veil (Fig. 67), at times compact and fibrous in structure, and again thinner, like a heavy cirro-stratus, through which the sun or moon may dimly be seen. Its average elevation is about 4 kilometres. It may result from the forward running of air forced up by the convergence of winds in the storm area of a cyclone, from the flow of warmer over colder air, or by mere radiational cooling in place, of a layer of relatively humid air—humid from the evaporation of alto-cumuli, perhaps.

Alto-cumulus (A. Cu).—The name alto-cumulus has been given to those detached, fleecy clouds, with shaded portions (Fig. 68), often occurring in closely packed goups and rows, that resemble enlarged cirro-cumuli. Their average altitude is approximately that of the alto-stratus—that is, 4 kilometres—and they presumably are formed by local convection, especially during fair, calm summer weather, when the relative humidity is low.

Strato-cumulus (St.-Cu).—Strato-cumuli are large rolls of dark cloud more or less connected with thinner clouds which together cover nearly or quite the entire sky (Fig. 69). Their bases are flat and at about the same height, generally 1.5 to 2 kilometres. They are formed by vertical convection, as is obvious from their rounded tops and flat bases at approximately the same level—the common saturation level.

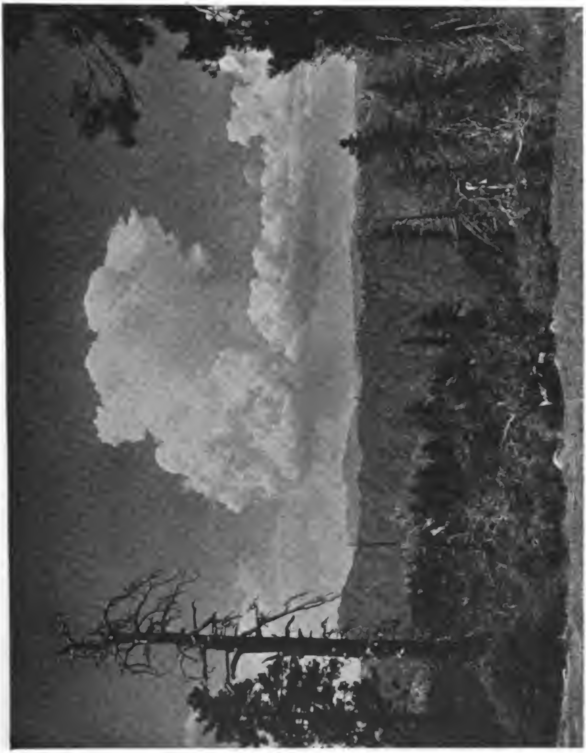
Nimbus (Nb.).—The nimbus is any thick, extensive layer of formless cloud from which rain or snow is falling. The average altitude of its under-surface is of the order of 1 kilometre. It is produced chiefly by some type of forced convection: the converging of wind currents as occurs especially in front of cyclonic centres, the upward deflection of winds by either land or cold atmospheric barriers, and the under-running of warmer by colder air. In part, however, the cooling and consequent condensation often is owing to the mixing of cold air with

FIG. 69.



Strato-cumulus, or roll cumulus, near Gap Mills, W. Va. (L. W. Humphreys, photo.)

FIG. 70.



Cumulus, seen near Mount Willson, Cal. (F. Ellerman, photo.)

warm, and to the transfer of warm air to a colder region, where it is cooled by contact, by mixing with cooler air, and by excess of radiation loss over radiation gain.

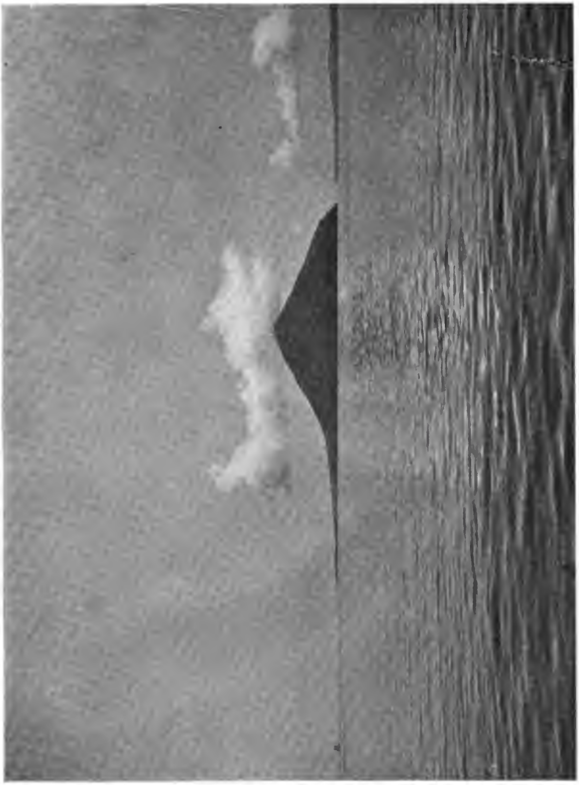
Fracto-nimbus (Fr.-Nb.).—The fracto-nimbus, popularly known as scud, is that low, detached cloud fragment, too thin and fog-like to produce rain, that occasionally is seen drifting rapidly beneath a heavy nimbus at an average elevation of probably not more than 100 to 300 metres. It seems to form only when there is considerable wind, and appears often to be caused by forced convection over cliffs or other obstacles.

Cumulus (Cu.).—The cumulus (Fig. 70), often called "woolpack," is a dense, detached cloud with a rapidly changing cauliflower head and flat base at the saturation level of rising air. Its illuminated portions are snow white, while the shaded parts are unusually dark. Its border is sharply defined and, when near the sun, very bright. The average altitude of the base is about 1.5 kilometres, and of the top rather more than 2 kilometres.

Cumuli are produced entirely by vertical convection induced by temperature differences. Hence they are always frequent in tropical regions, and also over continents at higher latitudes during summer. For the same reason, they occur over land most numerously of afternoons, and at sea late in the night. At times rather low cumuli form a sort of coastal fringe along the locus of upward convection—that is, a short way out over the sea at night, and a few miles inland during the day—that might, perhaps, be called coast cumuli—attendants of the land breeze and the sea breeze, respectively. They often occur over reefs and islands (Fig. 71), whose presence frequently is thus revealed while they themselves are still below the horizon. Occasionally they even parallel a large river on either side where there is rising air over the hills and bottoms and sinking over the cooler water. Further, since vertical convection depends only on the establishment of a proper vertical temperature gradient, it follows that cumuli may also form at high latitudes over the warmer portions of the ocean, or, indeed, wherever there is a sufficient temperature contrast between the surface and overlying air to induce strong upward currents.

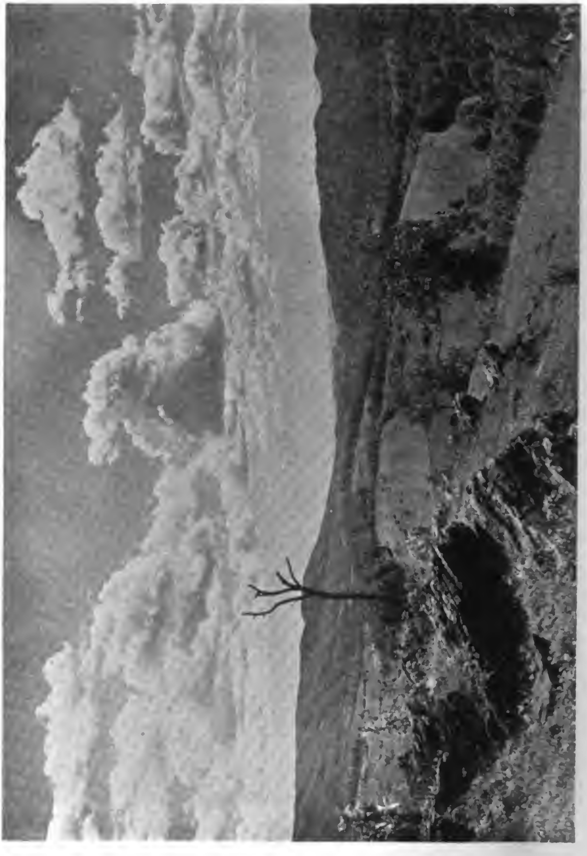
Fracto-cumulus (Fr.-Cu.).—During the initial stages, especially, of their development cumuli often are small, and appear

FIG. 71.



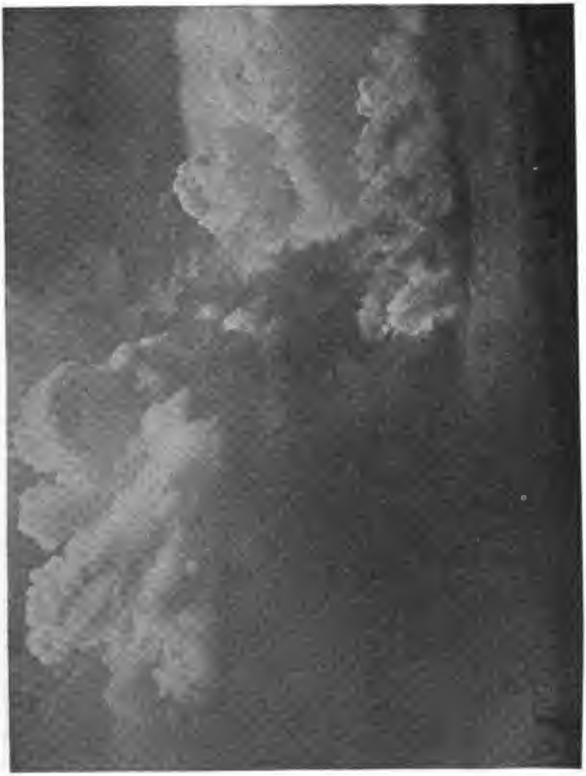
Cumulus over island—Krakatao. (E. E. Barnard, photo.)

FIG. 72.



Fracto-cumulus, in Monroe Co., W. Va., Peters Mountain to left. (L. W. Humphreys, photo.)

FIG. 73.



Cumulo-nimbus, over Loudoun Valley, Va. (A. J. Weed, photo.)

tattered and torn like detached and dissolving masses of fog (Fig. 72). While in this condition such clouds are often called fracto-cumuli.

Cumulo-nimbus (Cu.-Nb.).—The cumulo-nimbus (Fig. 73), a necessary accompaniment of every thunder-storm, is, as its name implies, a cumulus cloud from which rain is falling. It is very turbulent and much the deepest of all clouds, being anywhere from 1 to 4 or even 5 kilometres thick. Its times and places of occurrence and mode of formation are all the same as those of the cumulus.

Stratus (St.).—The stratus is a low, fog-like cloud of wide extent, often merging into a nimbus and again clearing away like lifted fog. Its average altitude is between 0.5 and 1 kilometre. It seems often to result from forced convection due to the underrunning of cold air, and also, perhaps, to the mixing of humid layers of different temperatures. In some cases, that of the "velo" cloud, for instance, in southern California, it is only sea fog drifting over relatively warm land.

SPECIAL CLOUD FORMS.

Although it might seem that the above cloud types, including their numerous gradations and transitions, are exhaustive, there nevertheless are several occasional forms sufficiently distinct to justify individual names and special descriptions.

Billow Cloud.—Billow clouds (Figs. 74 and 75), also called windrow clouds and wave clouds, occur in series of approximately regularly spaced bands, generally with intervening strips of clear sky. They usually form in the lower cirrus region—that is, at elevations of 6 to 8 kilometres—but may occur at any level from the surface—fogs are occasionally billowed—up to that of the highest cirrus. They are caused by the flow of one air stratum over another of different temperature and density and usually of different humidity.

It has been shown [82] that when two strata of air of different densities or vapor content flow over each other billows of great wave-length and often of large amplitude are generated in the

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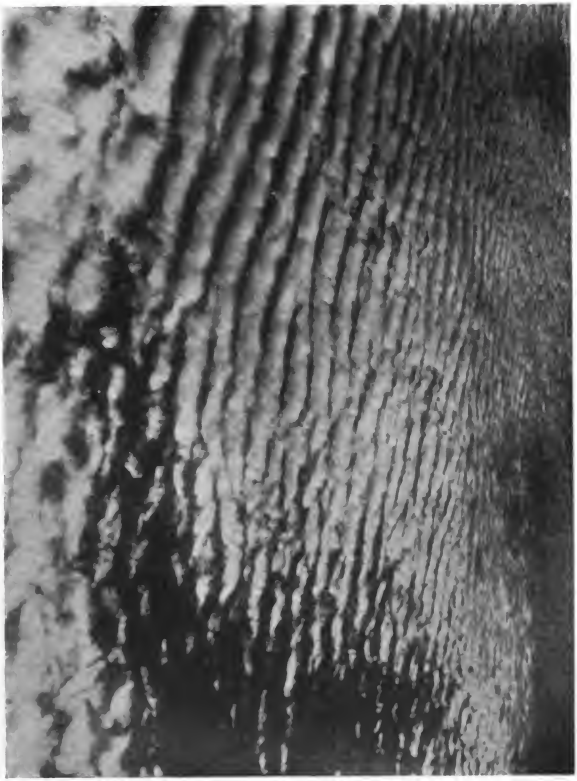
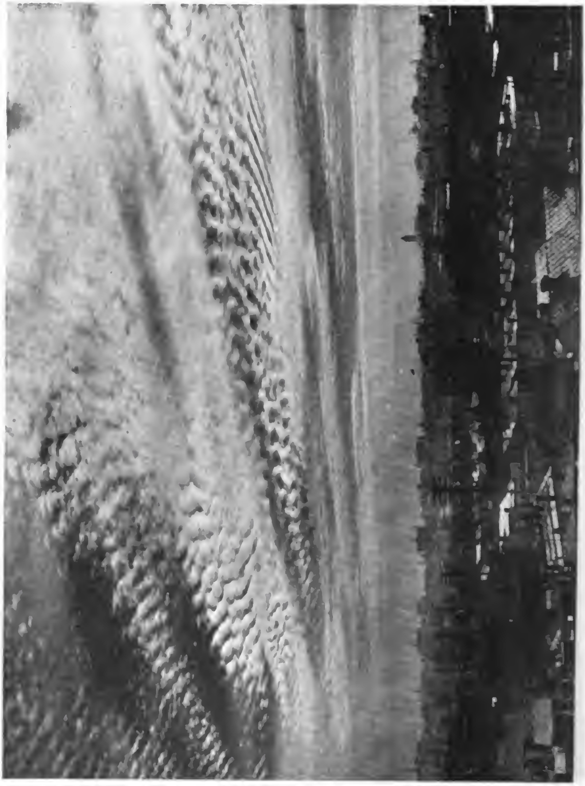
[82] Helmholtz, *Sitz. d. Akad. d. Wiss.*, Berlin, 1888, i, p. 646; 1889, ii, p. 761. W. Wien, *Sitz. d. Akad. d. Wiss.*, Berlin, 1894, ii, p. 509; 1895, i, p. 361. A. Wegener, *Beiträge Phys. d. fr. Atmos.*, 2 (1906), p. 55; 4 (1911), p. 23.

FIG. 74.



Billow cloud. (A. J. Henry, photo.)

FIG. 75.



Billow clouds, regular and irregular, over Washington, D. C. (A. J. Henry, photo.)

same manner that winds produce ocean billows. As the series of waves progress the atmosphere involved obviously rises and falls, and therefore is subjected to alternate dynamical heating and cooling, with the maxima and minima temperatures corresponding to the troughs and crests respectively. Hence when the under layer is wholly or nearly saturated the wave crests are cloudy and the troughs clear. If, however, the humidity is not high, it is obvious that wind billows may exist without the incidental clouds.

It is interesting to note that, although the billow cloud appears to consist continuously of the same mass, it nevertheless is rapidly evaporating on the rear or descending portion of the wave and as speedily forming on the front or ascending portion.

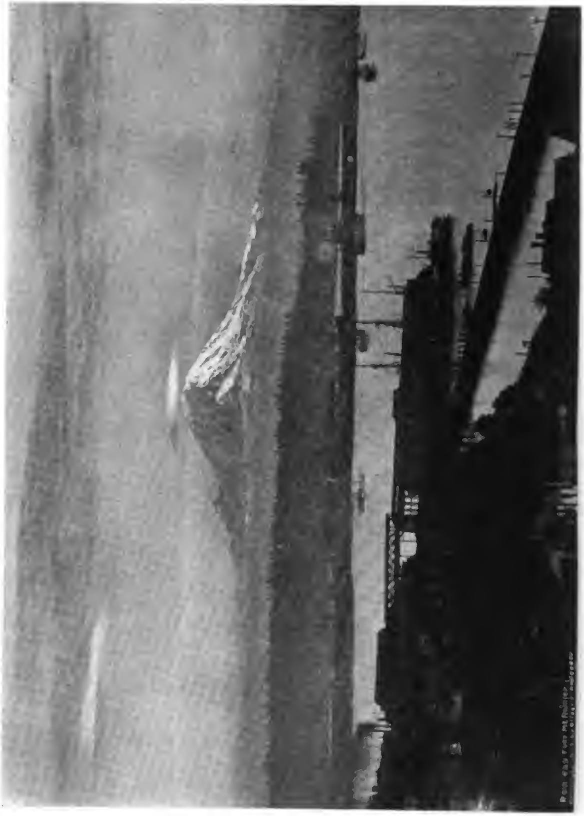
Lenticular Cloud.—The lenticular cloud (Figs. 76 and 77) is formed by the upward deflection of the wind over mountain peaks and, perhaps, rising air currents. In some cases, doubtless, the cooling is accentuated by the low temperature of the peak itself. In either case the cloud particles are rapidly evaporated as they are carried away, and the thickness of the whole mass reduced to zero at no great distance.

Crest Cloud.—The crest cloud is formed by the upward deflection of the wind by a long mountain ridge. It usually covers the higher slopes as well as the top, and, though called cloud by people in the valleys below, is likely to be designated fog by any one actually in it. Occasionally condensation occurs only along the upper reaches of the deflected winds, in which case the cloud belt is above and to the leeward of the mountain ridge.

In either case the individual droplets are quickly evaporated and the cloud form preserved only through continuous condensation from renewed air. It is permanent in the same sense that a cataract is permanent through the continuous supply of water by the stream above.

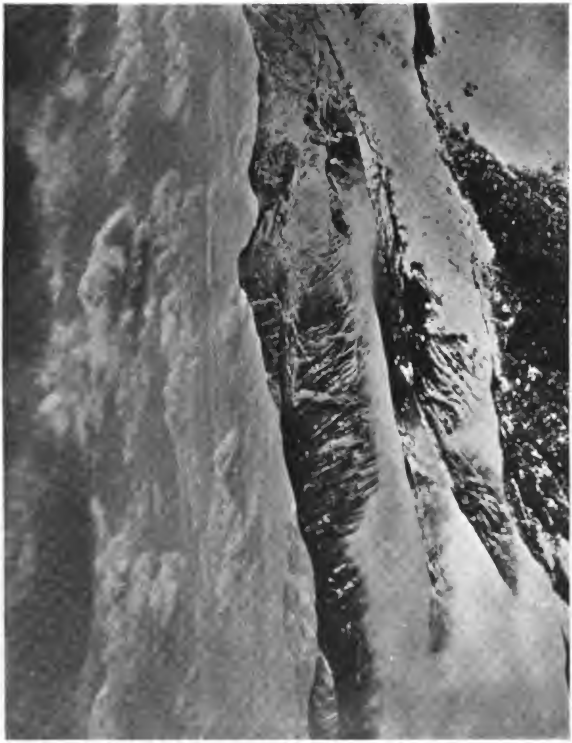
Banner Cloud.—The banner cloud (Fig. 78), as its name implies, resembles a great white flag floating from a high mountain peak. In strong winds the pressure to the immediate leeward of such a peak is more or less reduced, and the resulting low temperature, intensified, perhaps, by the mountain surface,

FIG. 76.



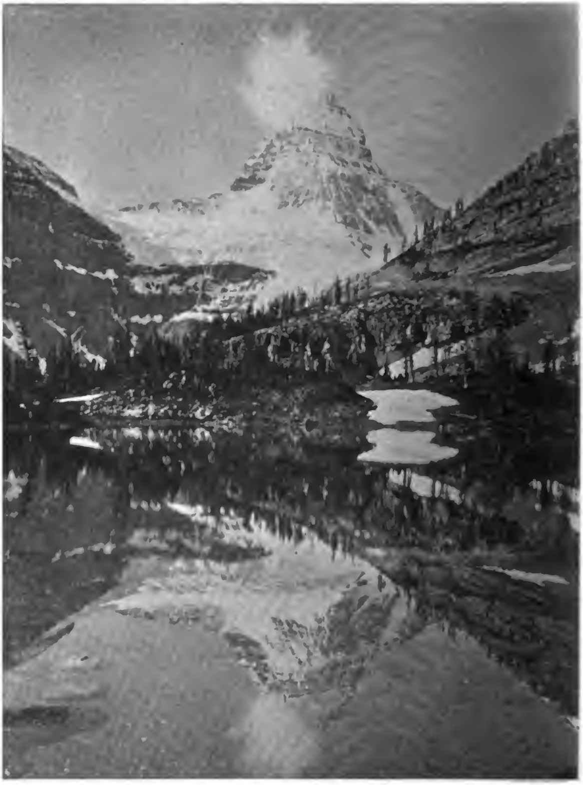
Lenticular cloud, over Mount Rainier. (O. P. Anderson, photo.)

FIG. 77.



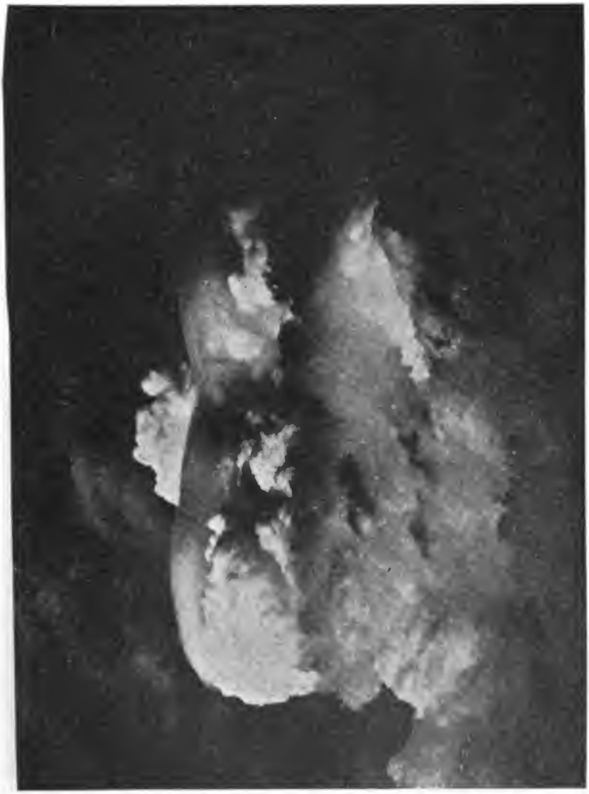
Lenticular clouds and fracto-cumuli over Rocky Mountains, ne Corona, Colo.

FIG. 78.



Banner cloud, Mount Assiniboine, near Banff, Canada. (C. D. Walcott, photo.)

FIG. 79.



Scarf cloud. (W. A. Bentley, photo.)

appears to be the cause of this singular cloud that, though continuously evaporating, as constantly re-forms in the turbulent wake.

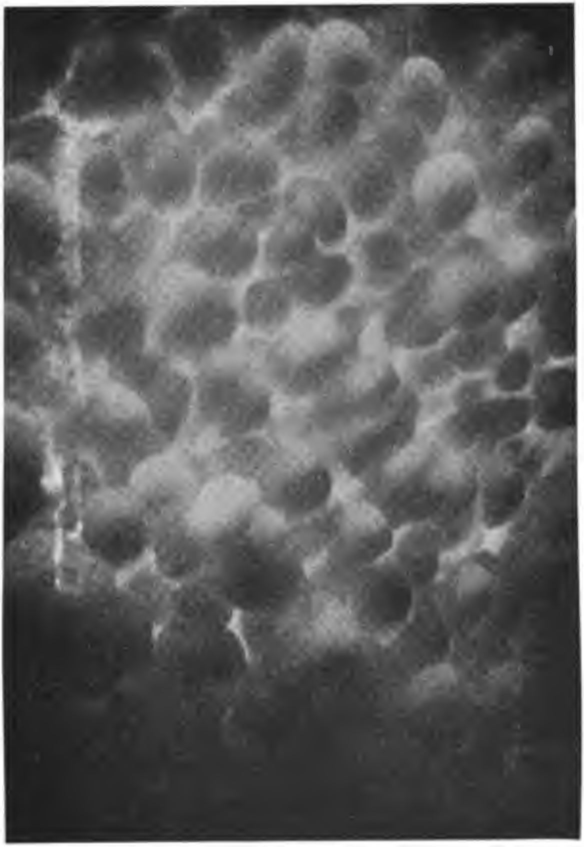
Scarf Cloud.—It occasionally happens that as a cumulus rises rapidly and to great heights a thin, cirrus-like cloud, convex upward, forms above the cumulus head and, at first, entirely detached from it. As the cumulus continues to rise the flossy cloud becomes more extensive and rests on the thunder head or heads. A little later it mantles the shoulders, the heads being free (Fig. 79), and may even drape the sides of the cumulus. In all stages it resembles a great silken scarf, hence the above-suggested name. It often is called false cirrus, but that name is now and better applied to a different formation. It has also been called cap cloud, but this is confusing, because the same term has long been applied loosely to any cloud that hovers above, or, especially, rests upon a mountain peak, and, besides, the cap analogy applies to only the early stages.

It is caused by the elevation and consequent expansion and cooling of the air immediately and to some distance above the rising mass of the cumulus. Generally this expansion of the superincumbent atmosphere produces no visible effect, but occasionally there exists a thin stratum of nearly saturated air in which an alto-stratus might form, or, indeed, later does form, and when this is lifted by the rising cumulus it immediately develops a local cirrus-like cloud. But if the saturated layer is thin, as it often is, the cumulus head may easily rise quite above it into dryer air, leaving the filmy cloud at practically its original level, the level of the humid stratum.

False Cirrus.—The name "false cirrus" formerly was applied indifferently to the scarf cloud, just described, and to those gray locks, to speak figuratively, combed out from old thunder heads by the upper winds. At present, however, the term usually is restricted to the latter phenomenon.

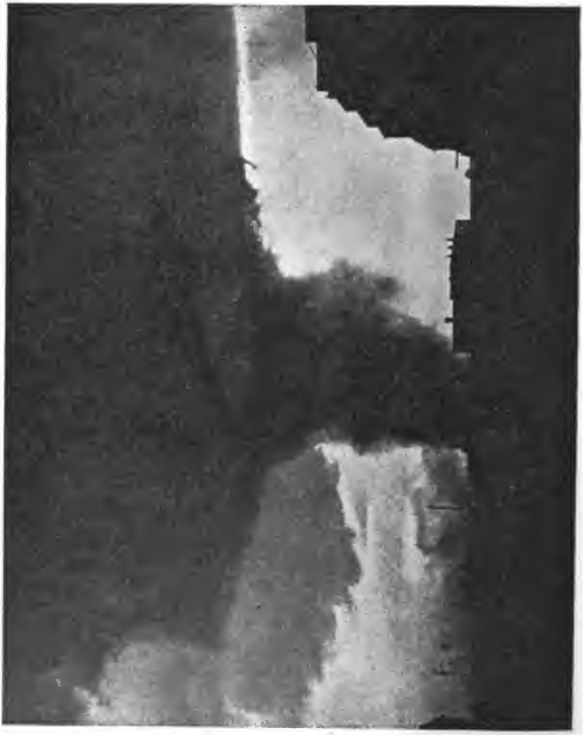
Although the lower atmosphere, up to at least 3 or 4 kilometres, generally is comparatively calm whenever cumuli are most conspicuous, it nevertheless occasionally happens that the highest thunder heads reach into a stratum of much greater velocity in which, therefore, the topmost portions of the cloud

FIG. 80.



Mammato-cumulus. (L. C. Twyford, photo.)

FIG. 81.



Tornado cloud, Antler, N. Dak. (W. H. Wegner, photo.)

are drawn out into wispy bands and fibres of snow crystals—a truly cirrus cloud whose peculiar origin is, perhaps, its only claim to the special name " false cirrus."

Mammato-cumulus.—The mammato-cumulus, sometimes called pocky-cloud, festoon-cloud, " rain balls," sack-cloud, or other similar name, is essentially a reversed cumulus (Fig. 80). It generally occurs in an alto-stratus or cumulo-stratus cloud, and seldom except in connection with a severe thunder-storm.

As is well known, ice in the form of hail and snow often occurs in the upper portions of large cumuli. If, now, this snow, say, is drifted out just above a stratus cloud, it is obvious that the cooled layer will descend at many different places, and that at each such place there will be produced a sag or pendulous bulge in the cloud base and, of course, a lift or rise wherever the counter-current obtains, thus producing the festooned appearance characteristic of this rather unusual cloud.

Tornado or Funnel Cloud.—The tornado cloud (Fig. 81) is only a funnel-shaped extension of, generally, if not quite always, a cumulo-nimbus. It is produced by the expansional cooling incident to the rapid rotation of the atmosphere in which it appears.

CLOUD HEIGHTS.

Relation to Humidity.—The heights of clouds have been measured by several obvious methods of triangulation, and from the data thus obtained it appears, as one might infer *a priori*, that whatever condition tends to increase the relative humidity tends also to lower the cloud levels, since the greater this humidity the less the amount of convectional cooling essential to condensation. Hence, in general, each type of cloud is lower in winter than summer, lower over humid than over desert regions, lower over oceans than continents, and lower with increase of latitude.

The table on page 644, copied from Hann's " Lehrbuch der Meteorologie," gives the average summer and winter heights of clouds at places of widely different latitudes.

Levels of Maximum Cloudiness.—When the frequency of clouds is tabulated with reference to elevation, maxima and minima are found with the layers to which they obtain growing thicker with decrease of latitude. This phenomenon, as a whole, is interesting, but it will be necessary, in discussing it, to consider the different levels separately, since each has its own explanation.

Fog Level.—As already explained, fogs, whether caused by radiation or advection, are surface phenomena, seldom more than 100 to 200 metres thick. Hence the surface of the earth, because of the fogs that form upon it, is itself a level of maximum condensation or maximum " cloudiness."

Cumulus Level (a), *Foul Weather Type.*—Since the cumulus and the cyclone nimbus both are due to vertical convection—the first thermal, the second forced—it is obvious that the base of each occurs approximately at the saturation level; that is, the level at which a mass of air rising from the surface will have cooled to its dew-point. Clearly, too, clouds cannot form at a lower level, the air there being unsaturated,—even if drifted in they would evaporate. Further, ordinary thermal convection usually does not extend to much higher altitudes, because the cooling of the rising mass through expansion and evaporation (the outer portions, at least, of the cloud evaporate) quickly brings it to or below the temperature of the surrounding air at the same level, except in the case of the largest cumuli, in

Average Cloud Heights in Kilometres.

Station	Ci.	Ci.-st.	Ci.-Cu.	A.-St	A.-Cu.	St.-Cu.	Nb.	Cu.-Nb. top	Cu. Top	Cu. Base	Fr.-Cu.	St.
	1. SUMMER, CHIEFLY APRIL TO SEPTEMBER.											
Bossekop, 70° N. . . .	8.32	6.61	5.35	4.65	3.42	1.34	0.98	3.96	2.16	1.32	. . .	0.66
Pavlovsk, 60° N. . . .	8.81	8.09	4.60	. . . .	3.05	1.85	. . . .	4.68	2.41	1.64	2.15	0.84
Upsala, 60° N.	8.18	6.36	6.45	2.77	3.95	1.77	1.20	3.97	2.00	1.45	1.83	. . . .
Potsdam, 52½° N. . .	9.05	8.08	5.89	3.29	3.63	2.16	1.79	3.99	2.10	1.44	1.71	0.68
Trappes, 49° N. . . .	8.94	7.85	5.83	3.79	3.68	1.82	1.08	5.48	2.16	. . .	1.40	0.94
Toronto, 43½° N. . . .	10.90	8.94	8.88	4.24	3.52	2.06	. . . .	. . . .	1.70		. . .	. . . .
Blue Hill, 42° N. . .	9.52	10.10	6.67	6.25	3.76	1.16	1.19	9.03	2.90	1.78	. . .	0.51
Washington, 39° N.	10.36	10.62	8.83	5.77	5.03	2.87	1.93	4.96	(2.45)	1.18	. . . .	0.84
Allahabad, 25½° N.	10.76	. . . .	11.28	. . .	4.50	. . . .	0.84	. . . .	1.76		. . .	. . .
Manila, 14½° N.	11.13	12.97	6.82	4.30	5.71	1.90	1.38	6.45	1.84		. . .	1.06
Batavia (year), 6° S.	11.49	10.59	6.30	. . .	5.40	. . . .	. . . .	. . . .	1.74		. . . .	0.70
	2. WINTER, CHIEFLY OCTOBER TO MARCH.											
Pavlovsk	8.74	7.09	5.98	. . .	3.17	1.50	. . . .	. . . .	1.60	1.12	. . .	1.00
Upsala	6.98	5.46	6.13	4.09	4.15	1.96	0.99	5.18	1.52	0.71	1.22	0.51
Potsdam	8.07	7.65	5.41	2.99	3.35	1.42	1.28	4.74	1.74	0.99	1.02	0.61
Trappes	8.51	5.85	5.63	3.82	4.27	1.61	1.05	3.85	2.37	. . . .	1.43	. . .
Toronto	9.98	8.53	8.25	4.18	2.50	1.54	. . . .	. . . .	1.33		. . . .	. . .
Blue Hill	8.61	8.89	6.16	4.57	3.66	1.60	0.65	. . . .	1.62	1.54	. . .	0.61
Washington	9.51	9.53	7.41	4.80	3.82	2.40	1.80	3.73	2.28	1.20	. . . .	1.13
Manila	10.63	11.64	6.42	3.90	4.64	2.32	1.49	3.14	1.82		. . .	. . .

which the amount of evaporation is very small in comparison to the total condensation. Hence foul weather cumuli and the lower cyclone clouds mark a second level of maximum cloudiness, commonly 1 to 2 kilometres above the surface.

Cumulus Level (b), *Fair Weather Type.*—During fair, calm, summer weather vertical convection is very strong, but, as the relative humidity is low, the resulting clouds are of the alto-cumulus type. Hence the alto-cumulus, 3.5 to 4 kilometres above the surface, marks a secondary or fair weather cumulus level of maximum cloudiness.

Cirro-stratus Level.—Since the different types of cirrus formed in the region of a cyclone (the cirro-stratus being, perhaps, the most frequent) are spread far in advance of the storm itself by the swift upper winds, it follows that they also mark a level of maximum cloud frequency.

Cirrus Level.—During fair weather thin cirri often occur, as already explained, at or near the top of the troposphere, due, probably, to that marked cooling of the upper atmosphere characteristic of " highs," and, as these are the highest of all clouds, it is obvious that they denote a final level of maximum cloudiness, one whose average elevation in middle latitudes is about 10 kilometres.

Regions of Minimum Cloudiness.—Between the levels of maximum cloudiness there obviously must be regions of minimum condensation. These are:

Scud Region.—Since one level of maximum cloud formation, including fog, is at the surface of the earth and the next at an elevation of approximately 1.5 kilometres, the average base height of the cumulus, it follows that the intervening region is one of minimum cloudiness, the absolute minimum being just above the highest fog. The name "scud region" might be appropriate to this space, since "scud" is, perhaps, the only cloud that occurs in it.

Intercumulus Region.—The intercumulus region of minimum condensation lies, as the name suggests, between the cumulus and alto-cumulus levels of maximum cloudiness. Its elevation is, roughly, 2.5 to 3.5 kilometres.

Alto-stratus Region.—As the alto-cumulus and the cirro-stratus mark adjacent levels of maximum cloudiness at the heights of about 4 and 8 kilometres respectively, it follows, as above, that the region between, at the heights of 4.5 to 6 kilometres, especially the higher alto-stratus region, must be one of minimum cloudiness. And this it is, because (*a*) it is above the level of diurnal convection and therefore of most cumulus clouds; (*b*) the clouds of intermediate level formed in cyclonic areas are not blown forward so rapidly nor, therefore, over such wide areas as are the cirri; and (*c*) the atmosphere at this level in anticyclones is nearly always dry, apparently dynamically warmed, and therefore non-cloud-forming.

Intercirrus Region.—Since the cirrus region furnishes two adjacent levels of maximum cloudiness, a foul (cyclonic) and a fair weather type, whose elevations are about 8 and 10 kilometres respectively, it follows that an intercirrus region of minimum cloudiness must lie between them at any elevation of, say, 8.5 to 9.5 kilometres.

Isothermal Region.—Obviously water vapor is not carried in any considerable amount beyond the limit of appreciable vertical convection. Hence, there being but little water vapor present, clouds cannot form in the stratosphere; that is, beyond an elevation of about 11 kilometres in middle latitudes.

There are, then, five principal levels of maximum cloudiness:

1. Fog level, surface of the earth or water.
2. Cumulus level, height above surface about 1.5 kilometres.
3. Alto-cumulus level, height above surface about 4 kilometres.
4. Cirro-stratus level, height above surface about 8 kilometres.
5. Cirrus level, height above surface about 10 kilometres.

There also are five regions of minimum condensation:

1. Scud region, 100 to 300 metres elevation.
2. Intercumulus region, 2.5 to 3.5 kilometres elevation, roughly.
3. Alto-stratus region, 4.5 to 6 kilometres elevation, roughly.
4. Intercirrus region, 8.5 to 9.5 kilometres elevation, roughly.
5. Isothermal region, beyond 11 kilometres elevation.

Cloud Depth or Thickness.—It is known that the thickness of clouds varies from the 8 or 10 kilometres of the most towering cumulus, usually associated with a violent hail-storm, down to that of a vanishingly thin cirrus. Systematic measurements of cloud thickness, however, have not been numerous. The best.

perhaps, were made at Potsdam and are given in the following table copied from Hann's "Lehrbuch der Meteorologie":

Cloud Thickness.

Cloud		A.-St.	A.-Cu.	St.-Cu.	Nb.	Cu.-Nb.	Cu.	Fr.-Cu.
Depth in metres	Average....	510	194	353	(590)	2070	669	214
	Maximum..	1310	370	1265	1240	>4600	2230	430
	Minimum..	105	50	50	160	340	90	70
Number of observations............		6	18	18	16	21	22	26

Cloud Velocities.—The velocity of a cloud is the velocity of the air in which it floats, except in the case of a stationary type—crest cloud, banner cloud, et cetera—or a billow cloud. With these exceptions, it therefore is approximately the gradient velocity at the cloud level, which varies with altitude, latitude, temperature, and pressure distribution.

Average values, observed at certain places, are given in the following table, also copied from Hann's "Lehrbuch der Meteorologie":

Average Wind Velocity in Metres per Second.

	Ci.	Ci.-St.	Ci.-Cu.	A.-St.	A.-Cu.	St.-Cu.	Nb.	Cu.-Nb. Top	Cu. Top	Cu. Base	Fr.-Cu.	St.
	1. SUMMER, CHIEFLY APRIL TO SEPTEMBER.											
Bossekop, 70° N....	18	18	11	13	11	5	6	..	7	7	..	7
Upsala, 60° N......	20	(39)	17	5	12	7	7	..	7	6	8	..
Potsdam, 52½° N...	22	24	13	11	10	9	11	9	8	6	7	7
Trappes, 49° N	23	23	23	15	13	9	10	14	10	9	8	10
Blue Hill, 42° N....	30	30	18	25	13	10	14	22	13	9	..	6
Washington, 39° N..	30	27	23	18	16	10	8	15	7	..	..	6
Manila, 14½° N....	13	16	3	..	11	4	..	..	..	..	..	..
Batavia (year), 6° S.	12	19	3	..	6	6	..	..	4	..	..	1
	2. WINTER, CHIEFLY OCTOBER TO MARCH.											
Upsala.............	23	13	18	..	13	12	6	18	12	..	12	..
Potsdam...........	28	20	24	16	16	12	13	28	10	(14)	12	10
Trappes............	23	19	27	18	14	11	16	..	12	12	11	10
Blue Hill...........	37	41	36	25	24	13	13	..	..	15	..	10
Washington........	35	30	33	21	21	15	12	21	11	..	..	10
Manila	13	16	3	19	4	8	6	..	..	..	..	..

(To be continued)

Nitrification of the Soil by Electricity. R. D. McCreery. (Communicated by the Author, Chicago, April 16, 1918.)—In this latitude it is estimated that 10 to 11 pounds of nitrogen per acre per year is precipitated to the earth by the natural electric disturbances in the atmosphere in the form of nitric acid. In the Tropics. where thunder-storms are more frequent and static conditions augmented, a larger amount is precipitated, and vegetation is therefore, as we know, more abundant. If we therefore discharge electricity through the soil and through the air and moisture in the soil, we not only stimulate the bacteria of life to greater activity known to occur after natural electrical discharges, but give them their principal plant food by producing nitric acid and nitrogen. The writer believes that the most rational and practical way to apply electricity to plant life is through the surface of the soil to the roots of the plant, because the two necessities, moisture and air, are always present and because the bacteria of life are located in the plant roots, and, further, because the electrically produced nitric acid and nitrogen are deposited where needed.

In coöperation with the Engineering Department of the Western Electric Company, Chicago, Ill., the writer has in the past year successfully tested a newly patented process embodying this principle. High-frequency current is literally driven in a spray through the surface of the soil from special distributing electrodes embedded in the earth (about 6 inches deep), arranged parallel to each other on two opposite sides of the field along the fence lines, out of the way of cultivation. The seeds, before planting, are coated with a finely divided, non-deteriorating metal, with the object of creating lines of low resistance and a condition analogous to the coherer of a wireless set. Tests were made on 11 acres of corn and a few rows of sugar beets at Lombard, Ill. The increase in the corn production is estimated at 30 to 40 per cent., with an increase in the value of the crop estimated at $25 to $35 per acre. It is claimed that the cost per acre for current and metallically coating the seed is less than 50 cents per acre, and the net cost of the apparatus installed less than $200.

Duo-negatives for Excessive Contrast. E. FELLOES. (*Camera Craft*, vol. 25, No. 2, p. 63, February, 1918.)—In photographing subjects with intense contrasts, the difficulty of securing the requisite amount of detail in the shadows without getting over-density in the high lights is a common experience. The use of films makes it possible to overcome this difficulty by a simple expedient. Two negatives are made, one for high lights with a short exposure, and the other fully timed for the shadows. The parts desired in each negative are then coated with celluloid varnish and the remainder removed with the well-known red prussiate and hypo reducer. When these two negatives are superposed in register, their combined effect is that of a properly timed negative. The method, of course, requires some dexterity in the blocking-out process, and is restricted to films of negligible thickness.

MILITARY HIGHWAYS.*

BY

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In its broadest sense a military highway can be defined as any highway over which equipment, men, or supplies are transported in the conduct of military operations. It may be located to serve a base of supplies, to connect the base with the front line of action, or to distribute supplies behind the firing lines. It is a unit of the transportation system which may involve in its entirety systems of highways, waterways, railways, tramways, and air routes.

In the conduct of modern warfare we now know that the highway plays no small part, because, in addition to its use as an avenue for marching troops, supply wagon trains, cavalry, and artillery, it affords a means of rapid transport that is easily, quickly, and economically constructed to carry heavy units of artillery and accessories, and the moving of large numbers of troops quickly from one part of the field of action to another by motor vehicles, as so often required in the present war. The value of possessing a comprehensive system of military highways becomes at once very apparent when we hear that France was practically saved by her ever-ready system of roads and the great number of available motor busses, which quickly conveyed her troops to the point of attack. But in this connection we must not confuse the fact that the system as now completed at the French fighting front was not complete to start with; but it consists in considerable part of extensions to main arteries which were built years ago according to a program having the civil as well as the military needs as a basis of design.

This, in fact, is the only basis upon which any comprehensive system of highways can be designed, and any system not based upon the civil as well as the military problems involved is not only uneconomical but unstrategic, because the present war has thoroughly demonstrated that the organization of all civil as well as military elements is absolutely essential to the rapid production of large supplies and their speedy delivery. In this latter the highways are great factors.

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* Presented at the Stated Meeting of the Institute held Wednesday, December 19, 1917, by Mr. E. W. James, General Inspector, Office of Public Roads.

The French road system as it existed has not provided local fighting line roads except as the forces have taken up positions along the highways, and in the location of the military roads in France there is apparent no idea of providing roads to accommodate traffic necessary on a hypothetical battlefield. Manœuvring for strategic advantage in position has considered the existing roads as topographical features. The battlefields have in part been controlled by the roads, rather than the reverse. In the system as built important centres were systematically connected. Through truck roads, on exceedingly good locations, were provided, and the radial system actually existing developed as a result of these primary considerations. Main roads from Paris to all large centres in France furnish Paris with a radial system, and similarly for the lesser cities of France. The development of the local network existed to some degree in the French system in August, 1914, but many miles of local roads have been built behind the fighting lines, not only to replace destroyed roads but to serve local military purposes. Reports from Italy state that four thousand miles of such roads have been built. Our problem, then, is not to develop a local network over small areas, but to provide, first, a series of main arteries between the large centres. In considering this phase of location in a large way it is well to see what is writ large in our national territory. For instance, if we should undertake to develop highways for military or any other purpose on the same scale that France has, there would be 32,000 miles of national roads in the state of Texas, and four times that mileage of intercounty roads; there would be as many main roads in New York and Pennsylvania as there were in Germany, and as many in New England as in Old England, Scotland, and Wales. The development of such a system in detail would be unwarranted by our present economic requirements in times of peace.

Further, the local construction of so close a network of roads would not be warranted over any one area to the exclusion of others. The total battle line on the Western Front, although extending from Switzerland to the Channel, is not so long as the distance from Washington to Boston. The overdevelopment of roads in such an area at the expense of a less development over a much larger area would obviously be a serious error. An enemy would simply go where the system did not exist and there attack.

To adapt the radial system of Germany or the old Roman system of Italy and France to the United States without modification or adjustment to American conditions and distances would be not only uneconomical but a military failure; because America has no one centre to build out from as a base to surrounding foreign countries and because the enemy would certainly not choose a port of landing supported by the best network of highways feeding it.

It appears plain, then, that the underlying principle of road location in a large way is to provide, first, the large open net of through roads over the entire area of boundary, choosing first those areas most open to attack.

Certain areas are obviously within this class; such as (*a*) the area about Long Island, comprising the New England states and New York; (*b*) the area about Chesapeake Bay, comprising much of New Jersey, Pennsylvania, Maryland, Delaware, Virginia, and North Carolina; (*c*) the Pacific Coast area of three states; (*d*) the Mexican border, comprising the southern part of Texas, New Mexico, and Arizona; (*e*) the Great Lakes area, comprising parts of the Lake states; and (*f*) the Gulf area, comprising parts of the southern Gulf and Atlantic states.

In addition to a large network of roads, connecting the centres of population in these areas, there should be through roads leading inland to important centres of manufacture and supply. The number of these necessarily depends on economic conditions. Roads should connect the Pittsburgh, Cincinnati, Detroit, Chicago, Birmingham, and other big industrial districts with the coasts. Such roads have already been found to provide a type of communication much needed, although they would appear on casual thought to be of little value, inasmuch as they parallel main rail lines with a lower and less useful form of travelled way or roadbed.

As the probable demands arising from war conditions on any particular part of the larger highway net cannot be foreseen, for the very simple reason that the actions of an enemy cannot be foretold, we find that the immediate economic and engineering considerations under peace conditions are those that must control in the engineering location in detail of these roads. The selection of any system of highways depends upon the following factors:

(*a*) Population and its distribution, (*b*) location of sources of raw products, (*c*) shipping points for such products, (*d*) location of manufacturing centres, (*e*) the amount of traffic between such centres, (*f*) the character of such traffic. Upon consideration of such factors highways fall into two classes: (*a*) primary and (*b*) secondary. The former are commonly called through roads, and connect a series of centres of population or commerce. These conditions prevail in the military as well as the civil classification, and the selection must be governed accordingly. The primary system must be designed in accordance with the demands of traffic and act as main arteries for the secondary system. The secondary system should be selected as feeders and connections to the primary system. It has been calculated quite accurately that twenty per cent. of the highways in America carry eighty per cent. of the traffic. Military expediency might bring local roads into the class of primary highways, should any area become a theatre for military operations, and every effort should be made to consider this point in the design of the system. Still the main arteries, the primary system alone, must be relied on back of the lines to carry the bulk of the load up to the zone of action where the secondary and additional roads are improved or built as required.

The design for highway improvements under ordinary conditions is not beyond a reasonable determination after a careful study of the traffic by means of traffic census and knowledge of the country to be served. The density of traffic under peace conditions never can equal that flowing from the demands of war, and any attempt to meet the possible military demands on all roads would result in a breakdown of the highway policy when considered from no other than an economical standpoint. For example, the Bar-le-Duc-Verdun road in France, about 50 miles in length, was forced to carry, during the months of the attack on Verdun, a continuous line of five thousand motor trucks throughout the day and night. Traffic moved in four lines along the highway, the speed of the vehicles varying with the line in which they travelled. Slow-moving horse-drawn vehicles moved along the shoulders, and the trucks moved at about a rate of twelve miles an hour, spaced fifty feet apart, with breaks of one hundred to two hundred feet now and then to allow for high-speed vehicles to shunt into line on passing the usual trains of trucks.

The construction of roads to carry such traffic is only advisable where it appears from the best military information that a similarly congested traffic might be likely to develop in certain very limited areas. For instance, as a part of the general network of roads already described certain sections from important railroad centres in the middle Connecticut Valley, the upper Hudson Valley, and the middle Susquehanna Valley might be constructed to take such traffic as the Bar-le-Duc-Verdun road carried to within easy striking distance of Boston, New York, and Philadelphia. But the mere statement of such a decision is open at once to the reply that to meet the possible needs practically any road in the system might become subject to the unusual conditions.

We are thrown back, then, in our detailed location and design very largely upon the same considerations as control highway construction in times of peace.

The military road should therefore be the most economical one, just as in the case of the selection under peace conditions; and, except in cases of emergency, the usual factors will apply. The most economical highway under all conditions is the one which results in the longest life for the amount of money invested and that serves its traffic with ease and safety. It is seen that the demands of traffic are the underlying basis of consideration for the improvement of any road and in turn govern the physical construction through the factors of location, character of improvement, type and width of surfacing, alignment, grade, etc. In general, a military road should be designed to carry traffic without delay or confusion, and with a minimum of effort.

Considerations of engineering location are controlled by the same details as for ordinary highway construction. A slight adjustment of some of our assumptions of design should be made. Grades should not exceed five per cent., except that an emergency maximum up to ten per cent. for not more than fifty yards may be allowed. Alignment should have no curves with radius less than two hundred feet, and a vista of not less than three hundred feet. The road foundations and bridge structures should be designed and built to carry at least six thousand pounds forward and eight thousand pounds rearward on a wheel base of 10 × 5 feet. The paved surface should be twenty feet wide and the grade thirty feet wide.

It is seen at once that, with the exception of the last, such requirements are warranted economically in time of peace only on a coarse network of important intercity roads such as that already outlined.

On the large coastwise net and through routes to the interior developments could, of course, continue as traffic demands increased. States having funds could fill in the net with smaller meshes, and the same requirements of design should ultimately apply to these as apply to the ordinary strands of the net, although a lower standard of design might at first be adopted. In many of our states such development already exists.

Much has been said lately of materials and methods of construction. It appears, from the most reliable and first-hand sources of information, that water-bound macadam, telford, V-drains, and stone base are the most effective purely military types of construction. We know that such type is not economical in many localities under circumstances of a piping peace. For this reason the type selected for use in our suggested system may be in accordance with current economic rather than possible military demands. But it is to be remembered that a requirement of maintenance controls under actual fighting conditions. Repairs must be made easily, rapidly, and without in the least interrupting or diverting traffic. The traffic carried by the Bar-le-Duc-Verdun road was astounding in its wear and could not be halted. The question of restoration of road surface called for much ingenuity, and was a matter of extreme expediency. Just what our American higher types of pavement would have suffered is hard to determine, as none of them is found to any great extent in the European zones of activity. Many of them would doubtless stand heavy pounding for a longer time than the macadam, but when rupture came the invariable requirement of immediate repair would force resort to materials and methods capable of rapid and effective application.

The records furnished us so far indicate that water-bound or clay-bound macadam has been generally used by the French and English immediately behind the Western Front. In the accounts, however, little differentiation has been made between the roads actually within the range of shell-fire, in what might be called the battle area, and those to the rear. It seems most likely that American practice can develop an improvement over the water-bound macadam patching in both areas, more especially on the main roads beyond range of shells. The advance that we have made in the last five years in the development of cold patch materials and their use indicates the great possibilities in this direction.

This method can be used on almost any type of wearing surface, from ordinary water-bound macadam to concrete or brick. So if we have any given system of roads constructed to meet the demands of normal traffic in times of peace, these roads may be repaired either with cold patches or water-bound patches if they ever come within the range of hostile artillery.

Roads built or rebuilt as the immediate accessories of an advance must be of materials that consolidate and furnish a travelled way in the least time. Such roads will probably be found in water-bound macadam or gravel. Likewise the repair of these roads, so long as they remain a part of the battle area, will have to continue in part of this type, or perhaps, under some conditions, of cold patch materials.

In this connection it is interesting to note that, when the War Department began the enormous task of building the National Army cantonments, a considerable mileage of camp roads and streets became necessary. The general opinion of those having the matter in charge was quite uniformly in favor of placing a gravel or macadam base at once wherever such materials were available. There were only a few exceptions to this plan in actual construction. The reason for this opinion was obviously that such types could be built most rapidly, and the same day a hundred feet of road was laid it could be used. Further, such construction would serve adequately as a foundation for any topping or surface treatment that might later be considered necessary. In fact, there has been considerable surface treatment, some bituminous macadam, in one or two cases bituminous concrete, and rather generally concrete platforms at warehouses constructed in the several cantonments. The company streets have generally been left as gravel or macadam.

These plans were arrived at independently of any information from the fighting front, as information was not then available. The decisions were reached solely upon a common-sense consideration of the highway problem.

The result of a departure from this general solution of the cantonment road problem is seen in detail in the work being done at Quantico, in Virginia. There it was decided to use concrete. At one time a daily rate of construction of five hundred linear feet of fifteen-foot road was reached by a single mixing plant. This is a rate of about three miles per month. But even this rate was not sufficient to enable completion of the work during the summer and fall. To continue operations into the winter it has become necessary to adopt expensive and unusual methods in order to insure the pavement against freezing and consequent serious damage. The blocks as laid are covered first by a framework of wooden slats; over this is spread a three-ply canvas tarpaulin. A layer of straw and stable refuse is spread on this, and the road remains thus covered about ten days to two weeks. It is necessary, also, to heat both the sand and large aggregate, and this is done by placing through the piles of materials metal cylinders in which fires are built. In addition, the water for gauging the concrete is heated before use, and thus the temperature of the entire mass is kept above the freezing-point until the block is poured and covered with the protecting canvas and straw mat. Of course, these precautions have materially reduced the rate of construction.

Under circumstances like these, which can occur in any latitude north of 33 degrees, and should be confidently expected anywhere north of 36 degrees, it is seen at once that the exigencies of rapid construction, immediate serviceability, and simplicity of method and materials throw us back upon the lower rather than the higher types of road surfacing.

Naturally these observations raise the question of costs. It has been stated in a reliable account that from ten to twelve thousand men have been used in one road organization on the British front in Flanders, that four thousand men were at one time on a single mile, and that stone has cost as much as $7.50 per cubic yard. The only statement pertinent is that cost is not considered. Much work is done by hand on the Western front, however, that by American methods might and probably would be done by machinery.

The question of shell holes is interesting, but the destruction from this cause is, according to the best information, much less in general than the layman supposes. Shells that bury themselves in loose earth before exploding burst almost at contact with a hard road surface and expend much of their force in the direction of least resistance. Consequently, shell holes on the roads are much shallower and smaller than in the fields. Moreover, it is costly business wasting ammunition in indiscriminate shelling of roads. Such destruction as occurs is usually the result of attempts to destroy motor trains or other transports passing over the roads, and is concentrated over a very limited length. Attempts to cut a road by shell fire are usually directed at points where aeroplane photographs indicate cuts or fills. The shelling aims to blow in the cut or blow out the fill. As a matter of fact, there appears to be little shelling of roads merely as such.

For these reasons the large bulk of repair work is the replacing of worn or scattered road metal. There appears to be nothing unusual in the methods used to make these replacements. A roller cannot commonly be used until the congestion of traffic is reduced so that it can be thrown on one-half of the road surface. Then the rollers are put on and the surface thoroughly repaired. Roads that have been gradually brought out of the battle zone by advancing forces are at the earliest moment practically rebuilt, being put into a condition as good as new, according to the reports at hand. If the same series of events occurred in the United States it appears probable that, with the persistence of heavy traffic even after the road has passed beyond shell fire, its reconstruction would have to be rapid and so conducted as to cause a minimum interference with traffic. For this reason it appears most probable that, regardless of original type, such reconstruction would quite generally be of gravel or macadam, at least until the fighting passed entirely out of the region tributary to the road.

We have no data that will lead to a choice of materials with respect to an effort to produce the effect of "camouflage." The French engineers have generally given up attempts to disguise a highway. The reason for this is rather obvious. The enemy locates these roads in the first instance from maps secured in time of peace. He corroborates his evidence by photographs taken from observation balloons or aeroplanes. The reflection of light from the regular road surface produces a road in the picture regardless of the color of the surface. The road always appears in the photograph in plain contrast with the surrounding terrain, from which the reflection is irregular. The local attempts at camouflage are now confined to the distribution of branches or brush so as to cast irregular shadows across the surface.

In this connection a detail of importance appears to be the suppression of dust. Although the roads are not gratuitously and promiscuously shelled, they are watched, and if a cloud of rising dust indicates the passage of a support train or ambulance, that cloud at once becomes a target. The use of light oils or other familiar dust palliatives is of advantage. This also reduces the chance of accident from driving into a fog of dust.

The question of road control is interesting because of the unmistakable demands arising from a military use of the roads. But at the present time the Government has control over only those roads on military reservations, and none but the Secretary of War would have authority to designate other roads of military importance. With respect to the existing present needs the Secretary of War has written as follows:

" . . . to the request . . . that the War Department make known the needs of the military situation in respect to the construction of roads with moneys appropriated by the Federal Post Road Act of July 11, 1916, I have the honor to make the following recommendations:

"(1) Federal aid under the act above mentioned should, in general, be granted only for roads such as can be designated 'through roads'—that is, roads leading from one centre of population or commerce to another. Assistance in building branch roads for automobiles or tourists to visit points of scenic or historical interest does not appear warranted when there is still such a pressing need of a good network of roads in most of the states.

"(2) The War Department recognizes certain areas as more likely to be the theatre of military operations than other parts of the country. Every effort should be made to persuade the state road commissions to complete the network of through roads within these areas, and Federal aid should not be granted unless these roads conform in construction to the needs of the military transportation likely to be used in the zone of the advance.

"The areas in question are:

"(*a*) The area about Long Island, including most of the states of Rhode Island, Maine, New Hampshire, Vermont, Massachusetts, Connecticut, and New York.

"(*b*) The area about Chesapeake Bay, including much of the states of New Jersey, Pennsylvania, Maryland, Virginia, North Carolina, and Delaware.

"(*c*) The Pacific Coast area, including California, Oregon, and Washington.

"(*d*) The Mexican border, including the southern part of the states of Texas, New Mexico, Arizona, and California.

"(*e*) The Great Lakes area, including the states of Ohio, Indiana, Michigan, Illinois, and parts of Wisconsin and Minnesota.

"The following requirements as to construction within the areas mentioned are recommended: (1) Roads to have a smooth, hard surface of broken stone or a pavement not less than 20 feet in width and capable of supporting the loads hereafter specified for bridges. (2) Grades not to exceed 5 per cent., except for short distances (less than 50 yards), where they shall not exceed 10 per cent. (3) Bridges to be of iron or masonry, and of type to support loads of a 6-inch howitzer (3000 pounds on front wheels and 6500 pounds on rear wheels, distance between axles 12 feet, width of wheel track 5 feet) or a 3-ton truck loaded (6000 pounds on front wheels, 8000 pounds on rear wheels, distance between axles about 10 feet, width between wheels, centre to centre, about 5 feet). In hilly country, where road foundations are necessarily in hardpan or rock, the importance of artificial surfacing is less important than the completion of a well-drained road bed joining the roads in the adjacent valleys; and it is therefore recommended that in such cases the completion of an unsurfaced graded road be completed before the requirement as to artificial surface is enforced.

"In general the projects already submitted by state road commissions comply with the first military requirements, as stated above, and it is believed that the Department of Agriculture would meet with little or no opposition in enforcing them as recommended."

In the light of military requirements, the matter of road control is emphasized just as it is by the ordinary economic requirements of the nation at large. It is the one really serious difficulty in our present road situation.

There are small groups of roads in specially created road districts, built with the proceeds of bond issues for which the district is liable. These roads are frequently under the sole charge of bond trustees. In the same county or township there may be other roads under the jurisdiction and control of the county commissioners. Still other roads in the same county may be jointly under the state and county, the latter being directly responsible for maintenance and the former having none but a supervisory authority so long as the county maintains properly. Then there may be a state road across the county over which the state has full control to build and maintain. Finally, there may be a Federal Aid road, and this road may be a section of any one in these previous categories. Over the Federal Aid road once constructed the Government has no control except that if the road be not properly maintained the Government may refuse further aid, at the end of four months, to the particular local unit responsible for the maintenance.

Under such a dispersion of authority it has been in the past. and doubtless will continue in the future to be, almost impossible to secure the systematic continuous construction and maintenance of important roads where the jurisdiction and the control of funds are lodged in so many different bodies. It is quite apparent, from the information that comes to us from Europe, that some centralized control of the roads over a considerable area will become imperative with the occurrence of special military needs. Roads will have to be built and maintained regardless of the local political boundaries, and it appears that any administrative unit less than the state would fail to serve adequately the demands that will arise. Such condition, however, is no more pertinent to the possible military uses of highways than to the present economic demand, and the same degree of centralized control is essential in peace as would be required in time of war. The gradual extension and development of this control is therefore warranted in peace as much as it would ever be, for only through such control can the completion of the most necessary roads largely considered be brought about, an advantageous uniformity of construction be attained, and adequate maintenance at all times be assured.

The general conclusion from these observations is that the planning and use of highways for military purposes introduces no new or essentially different principles and only a few altered assumptions. These assumptions are all in the direction of improved and heavier construction in most localities. Some states are already building on designs that are adequate in all respects except perhaps width of roadway and weight of bridges. But many are not doing so.

Some correlated system of roads in certain large areas should be laid out and, regardless of local units and political boundaries, constructed to form a large net of general control roads. A few trunk connections should be made with industrial centres in the interior.

Whether the United States is pursuing a policy in accordance with the demands of modern warfare can best be studied from the standpoint of the administration of the new Federal Aid Road Act which grants Federal aid to the various states. Under this act the states are required to organize a state highway department, submit projects for construction upon which it expects to expend Federal Aid funds, and guarantee that funds for the maintenance of completed projects will be provided by the local units having jurisdiction over the roads constructed.

After one year's operation all of the states have conformed to the requirements of the act and become the units with which the Federal Government coöperates. The several state highway departments are effective organizations for the designation, construction, and maintenance of certain selected roads. Previous to the enactment of this act most of the highly developed and thickly populated states had independent highway departments that had done very effective work. Many of these, such as Massachusetts, New York, Pennsylvania, New Hampshire, Maryland, Connecticut, and California, which have already comprehensive systems of improved roads based upon economical factors are in the groups outlined in the letter of the Secretary of War. Many civic organizations advocating through road construction have been influential in securing some degree of contiguous improvement. The War Department has also designated a few definite roads as essential to military activities, and many of these are being improved as fast as funds and economy will allow.

In those states along the coasts and border a large part of the Federal Aid is actually going on sections of a network that would serve adequately for military purposes. The design and type of construction are in general accord with the suggestions of the War Department. Of course, all such work is the result of voluntary coöperation. The Federal Government at the present time has no authority to force construction at any point or in any particular manner, and whatever good results are being obtained must fairly be attributed to similarity of engineering judgment, and to the harmonious relations and tactful conduct of affairs between the several governmental units concerned. There are certain directions in which the general program of road construction might be improved. The work among the various states might be more carefully correlated; the designs might be standardized in a few important details, and a program of work devised that will favor the completion of some articulated system of roads. Until such details have been worked out we shall not be able to close the final weak links that abound everywhere in our highway systems, or to provide adequate construction in poor or backward localities. Only when these things are accomplished will our highways at last possess the essential final elements that bring them up to their full effectiveness in time of peace and make them a dependable resource in time of war.

An Optical Ammeter. P. D. FOOTE. (*Journal of the Washington Academy of Sciences,* vol. 8, No. 4, p. 77, February 19, 1918.)—The high precision in the measurement of temperature possible by the use of a properly designed Holborn-Kurlbaum optical pyrometer equipped with a suitable pyrometer lamp is well recognized. If the lamps are operated below 1300° to 1500° C. the calibration of the pyrometer will not change appreciably after years of ordinary use. These two factors—accuracy of photometric settings and constancy in calibration of the lamps—permit the adaptation of this method of photometry to the measurement of current.

The range of current which can be measured by any one system of lamps exceeds 1 : 2, and lamps having filaments of different sizes may be used for a large range in value of currents. Assuming that a photometric match may be made with an error limit of 0.5 per cent., which is reasonable for precision photometry of this type, it can be shown that the current is determined with an error limit of 0.03 per cent.

HEATS OF DILUTION AND THEIR VARIATIONS WITH TEMPERATURE.*

BY

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1. *Enunciation of the Purpose of the Investigation.*—By thermodynamic calculations the variation of the heat of dilution of a solution with change of temperature is equal to the rate at which the heat capacity of the solution changes with the concentration. Previous determinations of the heats of dilution have failed to support this relation in some cases.[1] It is the object of this research to find out, if possible, whether this discrepancy is real or the result of experimental error.

2. *Method of Obtaining Heats of Dilution.*—In determining the heats of dilution it is necessary to start with an initial concentration of the solution and measure the amounts of heat L_m evolved as the solution is diluted by adding to it mass m of water. The values of L thus obtained plotted against the values of m give a curve whose tangent at any point is the value of the heat of dilution for the corresponding concentration.

3. *Problem of Apparatus.*—Magie's experiments on heats of dilution were performed with silver calorimeters exposed to room temperature. On account of continual temperature change when the readings were taken it was necessary to make corrections, and these were somewhat uncertain. The problem was to devise a piece of apparatus that would measure the heat of dilution as accurately as possible. At the suggestion of Prof. H. L. Cooke, I decided to employ a method of continuous flow. In designing the several parts of the apparatus I was greatly assisted by Professor Cooke's experience and advice. The apparatus was planned so that either mercurial or platinum resistance thermometers could be used. After a thorough consideration of resistance thermometers they were abandoned in favor of mercurial thermometers, because the latter simplified the manipulation of the apparatus so that one person could use it.

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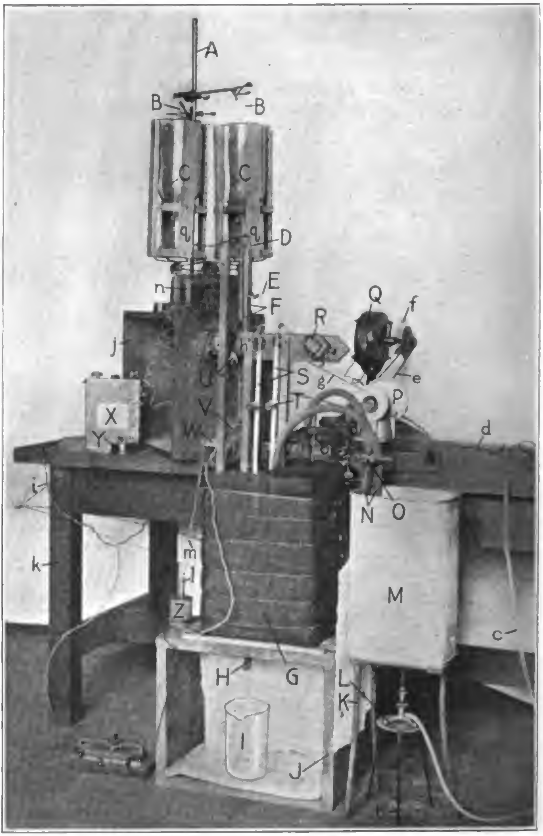
* Communicated by the Author.

[1] Magie, "Heats of Dilution," *Physical Review*, vol. xxxv, October, 1912.

FIG. 1.



4. *Description of Apparatus.*—The principal parts of the apparatus were a delivery system by which equal masses of water and solution flowed continuously through the apparatus, and a thermostatic system by which the water and solution in separate tubes were brought to the same temperature, then mixed in a Dewar flask and the change in the temperature of the mixture noted. The complete arrangement of these systems is shown in Fig. 1, in which the several parts are marked with letters. Each part has the same letter in all the diagrams.

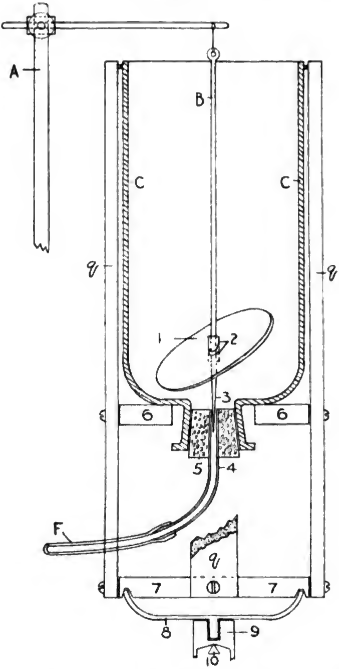
The delivery system consisted of two glass tanks, *C*, in which the liquids to be used were contained. These tanks were supported upon the pans of a balance, *n*, and the liquids were conducted from the tanks to the thermostatic system through rubber tubes which were supported at a point in line with the centre knife-edge to preserve the sensitiveness of the balance.

The device for controlling the flow of the liquids was the same in both tanks, hence the detailed diagram given in Fig. 2 shows only the right half of the delivery system. The stand, *A*, supports a small glass rod, *B*, on the lower end of which is a long conical valve, 3, which controls the rate of flow of the liquid. Valve 3 remains stationary while the tank moves up or down, thus decreasing or increasing the area of the opening through which the liquid leaves the tank. The tank having the greater mass of liquid will move down, opening its valve, and at the same time the other tank having less mass will move up and partly close its valve, thus automatically keeping the masses of liquids in the two tanks equal.

A test of this device showed that the balance oscillated continuously. Instead of two equal streams, there was a jet first from one tube and then from the other. A thin glass disc, 1, fastened to rod *B* in a horizontal position, decreased the number of vibrations, but did not overcome the difficulty. But by tilting the disc the least movement of the liquid up or down forced valve 3 against the side of the outlet tube, 4, causing friction which arrested the balance before it swung too far, and so the desired continuous flow was attained.

A detailed diagram of the thermostatic system is shown in Fig. 3. The several parts of this system were placed in a rectangular tank, 18, which was insulated with felt, 19, and filled with water. Two silver tubes, 9, received the liquids from the delivery system and carried them to the mixing tube, 2, of the Dewar flask, 1. Each of these silver tubes was 2 millimetres in diameter and 3.8 metres long. This length of tubes gave the liquids which they conveyed abundant opportunity to acquire the constant temperature of the water in which the tubes were immersed. A vigorous circulation of the water was maintained by the revolving stirrer, 20.

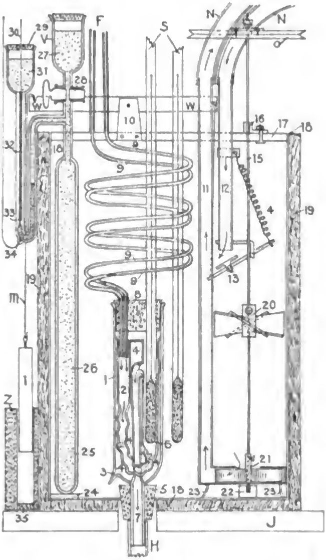
FIG. 2.



The mixing tube was corrugated to aid in mixing the liquids, and was insulated by vacuum to prevent transfer of heat. Arrows show the course of the mixture flowing around the thermometer bulb, 6, and out through the overflow tube, 7. The other thermometer, *S*, indicates the temperature of the water in the thermostat.

The temperature of the thermostat was maintained at the desired point by means of a circulatory system, which consisted of a centrifugal pump, 21 (Fig. 3); an outlet tube, 11; a copper coil in the tank, *M* (Fig. 1); a return tube, 12 (Fig. 3); and a control valve, 13. The centrifugal pump forced a small amount of water from the thermostat through the system and back to the thermostat again. The copper coil was surrounded with ice or immersed in hot water, according as the desired temperature of the water in the thermostat was below or above 20° C.

FIG. 3.



In order that the right amount of cold or hot water might be delivered to the thermostat to maintain constant temperature, a sensitive control system was constructed. This system consisted of a long tube, 25 (Fig. 3), filled with toluene; a capillary U-tube, 32, containing mercury for closing an electric circuit which operated a solenoid, *Z*; and a control valve, 13, which was opened or closed by a solenoid plunger, *I*, acting through lever, *W*.

When the stopcock, 28, is closed the expansion of the toluene forces the mercury, 33, up to meet a wire, 30. This unites the wires 30 and 34 which are connected in series with a solenoid, *Z*. Wire 30 is pushed down by a cam, *U* (Fig. 1), at a constant rate until the push-rod holding the wire slips off the large part of the cam, breaks the circuit at the cam, and quickly pulls the wire out of the mercury. This operation was repeated every ten seconds. The advantages of this moving wire were the prevention of sparking between the mercury and the wire and the stopping of the flow of hot or cold water into the thermostat at short intervals so that the lag in the controller would not allow too much water to enter. Alcohol, 31 (Fig. 3), kept the surface of wire 30 clean. A pinchcock, *O* (Fig. 1), served for the rough adjustment of the flow through the circulatory system. With a careful adjustment of the pinchcock *O*, the temperature would not vary 0.001° for a period of five minutes while readings were taken. When the liquids ceased to flow the temperature would change two- or three-hundredths of a degree before the controller acted. There would be a similar amount of change in the opposite direction when the liquids began to flow.

5 *Tests of Correct Working of Apparatus.*—At first each silver tube in the thermostatic system was only 1.9 metres long. Tests were made by running water through these tubes separately and jointly to determine if the temperature of the water as it left the tubes was constant under all conditions when the temperature of the thermostat was kept constant. These tests showed that a change of five degrees in the temperature of the water as it entered these tubes produced a change of five-thousandths of a degree in the temperature of the water leaving the tubes. To prevent this change of temperature the length of these silver tubes was doubled. After this was done the temperature of the water leaving the tubes remained the same even with a change of

twenty degrees in the temperature of the water as it entered the tubes.

A strong solution of common salt was run through each tube separately and then through both at once, with the result that the thermometer always registered the same as when distilled water was used. Usually the thermometer in the Dewar flask registered four- or five-thousandths of a degree higher than the thermometer in the thermostat. This, no doubt, was due to the vigorous stirring in the mixing tube. If the thermometer in the thermostat stood at 15.000° C., the thermometer in the Dewar flask always registered 15.004° C. when water or salt solution alone flowed through the apparatus.

When distilled water flowed through one tube and an equal mass of salt solution flowed through the other (the thermometer in the thermostat still standing at 15°), the thermometer in the Dewar flask changed from 15.004° C. to some other temperature —for example, to 14.754° C.—owing to the heat of dilution, and continued to register this temperature until the tanks of the delivery system were empty. This zero method allowed the 0.250° C. change of temperature to be measured by the thermometer in the Dewar flask alone, hence no correction for slight differences in the two thermometers was needed.

The contents of the Dewar flask were only a few thousandths of a degree lower in temperature than the surrounding thermostat, hence no radiation correction was necessary. When the flow of liquids stopped, the thermometer in the mixing tube continued to register the same temperature for some minutes, showing good insulation. Even the heat arising from the friction of the liquids running through the mixing tube was compensated by the zero method. Electric hammers were arranged to tap both thermometers before each reading was taken, magnifying glasses fastened to each thermometer aided materially in estimating to thousandths of a degree, and the fact that both thermometers remained constant for several minutes while readings were taken inspired great confidence in the correctness of the readings.

6. *Method of Taking Measurements.*—In cases when the solubility permitted, the initial solution consisted of 25 gramme-molecules of water to one gramme-molecule of salt. The initial concentration, on the convention that $c = 10000/N$, is therefore 400. By running this solution through the apparatus and an equal

mass of water the concentration is changed to 188 in the case of sodium chloride and to different values for other salts. In order to have uniformity in tabulating measurements, the change in temperature resulting from this first dilution was placed in a column marked 1. When this solution was diluted a second time by adding again a mass of water equal to the mass of the solution, the change of temperature was placed under the heading marked ½, the third dilution under ¼, etc. This process was continued until the solution was so dilute that no change of temperature could be detected.

There was no advantage in repeating the measurements at the same temperature, because the results were always the same. But since there is a continuous change in the heat of dilution as the initial temperature is varied, it was of advantage to make a large numbers of measurements with a small increase of temperature in each successive measurement. A variation of two degrees for the chlorides and of five degrees for the other solutions was used. The change in temperature resulting from dilution was plotted against the initial temperature of the solution and water before mixing and a smooth curve passed through these points. This method tended to eliminate small errors in the thermometer by using a different part of the scale of the thermometer each time. It also compensated for the personal factor, since a different number was estimated each time.

7. *Method of Computing Heats of Dilution.*—As the method of calculation was the same for all solutions, a full explanation for any one of them, *e.g.*, sodium chloride, is sufficient. The concentrations for the several dilutions of the sodium chloride solution were calculated and found to be 400, 188, 91.1, 44.9, and 22.3. The heat capacities corresponding to these concentrations were interpolated from tables given by W. F. Magie, *Physical Review*, vol. xxv, No. 3, and were found to be 448.2, 949.5, 1864, 3994.3, and 8043.8, respectively. The heat capacity multiplied by the change of temperature gives the number of gramme-calories of heat which must be introduced into the solution or withdrawn from it to keep the temperature constant.

To compute the heat of dilution of sodium chloride at 10° C., the point is found at which curve 1 (Plate A) cuts the 10° line. This is at −0.297°. This number, multiplied by the heat capacity 949.5, gives −282 calories, which is the value of L for concen-

PLATE A.

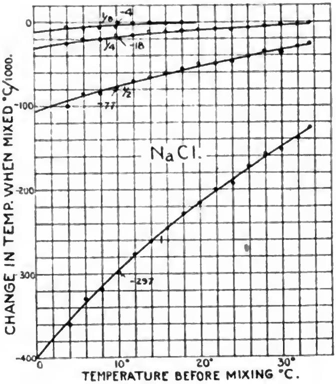
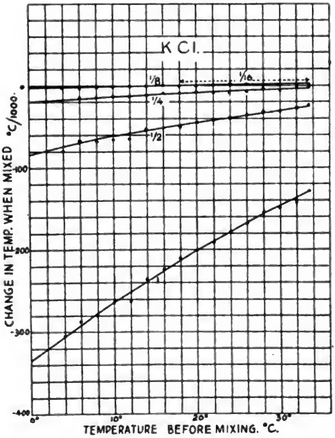


PLATE B.



tration 188. Curve ½ cuts the 10° line at -0.077°, and this number, multiplied by 1964 and added to -282, equals -433 calories, which is the value of *L* for concentration 91.1. Curve ¼ cuts at -0.018°. This number, multiplied by 3994.3 and added to -433, gives -505 calories. Finally, curve ⅛ cuts at -0.004°, which, multliplied by 8043.8 and added to -505, gives

PLATE C.

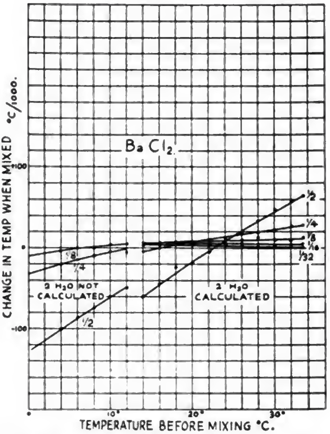
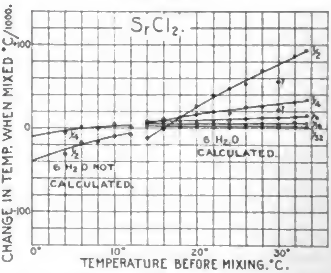


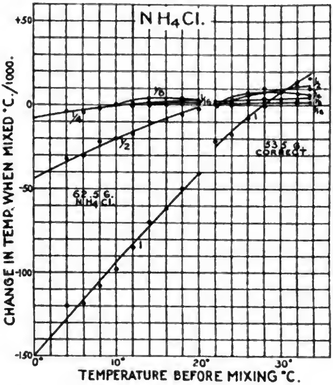
PLATE D.



—537 calories. These values of *L* were plotted against the corresponding concentrations and the several points connected by a smooth curve which gave the curve marked 10° in Plate F. This same process was followed in determining the curves for other temperatures.

In part of the measurements for barium and strontium chloride the water of crystallization was not allowed for. At temperatures below 20° by mistake nine grammes too much ammonium chloride was used. It was supposed to be possible to interpolate the correct values from these results until it was too late to repeat the measurements. The curves are similar to the correct curves, but slightly displaced. It was thought worth while to give these curves, as they show the effect of changing the initial concentration.

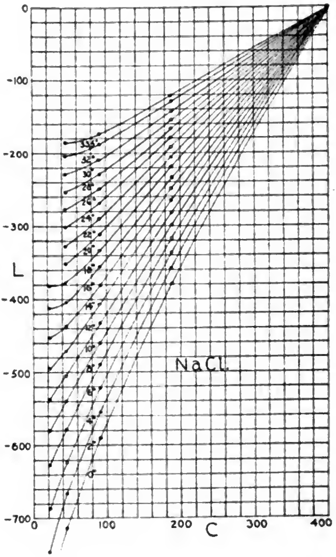
PLATE E.



Sodium and potassium hydroxide have great affinity for water. As it was impossible to determine the weight of water in the samples used, a solution of each was made and the concentration was determined by finding the density of the solution. The first solution contained 13.5 gramme-molecules of water to one gramme-molecule of sodium hydroxide. The second solution contained 15.2 gramme-molecules of water to one gramme-molecule of potassium hydroxide. These concentrations were about double the initial concentration used in sodium chloride, hence the first curve is marked 2.

Barium nitrate dissolves slightly in water; thus one-eighth of a gramme-molecule of this salt was dissolved in 25 gramme-molecules of water for the initial solution.

PLATE F.



8. *Statement of Relations to be Examined.*—The formula to be tested is

$$\frac{dl}{d\theta} = -\frac{dH}{dm} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \quad (a)$$

in which l stands for the heat of dilution and is positive when heat has to be removed to keep the temperature θ constant as dilution proceeds. H is the heat capacity of the system, consist-

PLATE G.

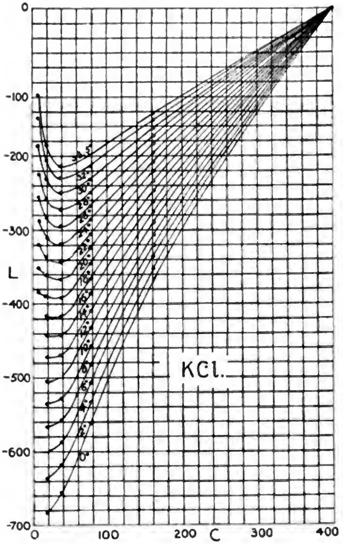
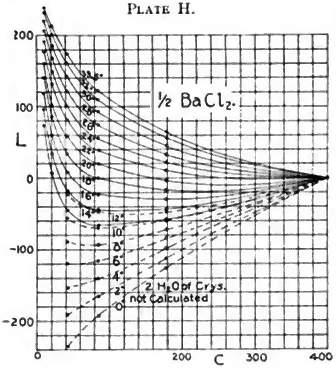


PLATE H.



ing of one gramme-molecule of a salt dissolved in N gramme-molecules of water and an additional mass of water. m is the mass of the solution. Magie has assumed $\frac{dH}{dm}$ to be constant with respect to temperature.[2] This allows formula (a) to be integrated into the form

PLATE I.

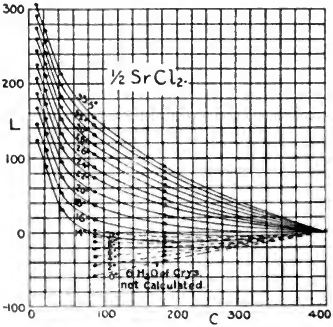
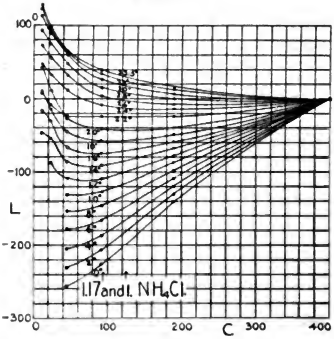


PLATE J.



$$l_2 - l_1 = -a\,(\theta_2 - \theta_1) \quad \text{(b)}$$

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[2] Magie, "Heats of Dilution," *Physical Review*, vol. xxxv, October, 1912.

PLATE K.

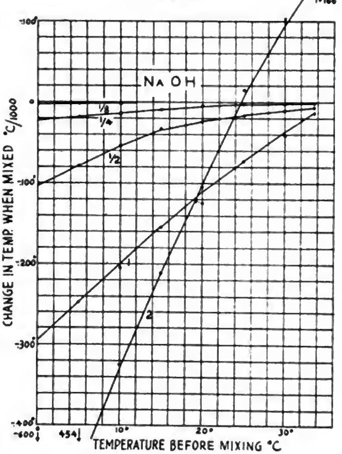
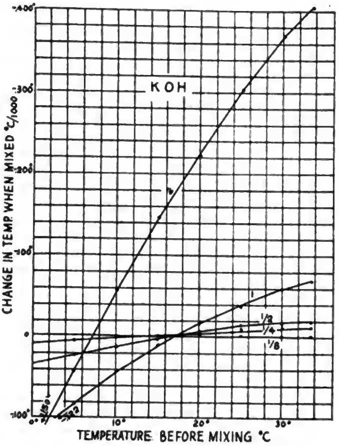


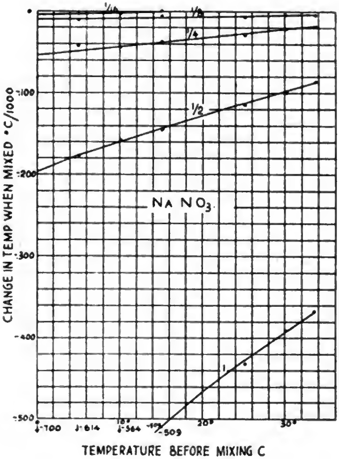
PLATE L.



Since the heat of dilution is obtained by starting with an initial concentration of the solution and measuring the amount of heat L_m evolved as the solution is diluted by adding to it mass m of water, equation (b) may be written in the form:

$$\frac{dL}{dm_2} - \frac{dL}{dm_1} = - \frac{dH}{dm}(\theta_2 - \theta_1) \qquad \text{(c)}$$

PLATE M.



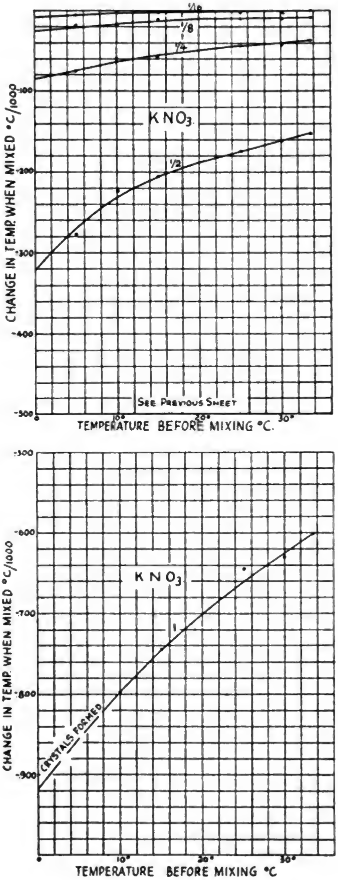
This expression integrated with respect to mass and the temperature assumed to be constant gives

$$(L_m - L_o)_2 - (L_m - L_o)_1 = -(H_m - H_o)\ (\theta_2 - \theta_1) \qquad \text{(d)}$$

where subscripts m and o refer to final and initial concentrations. Since L_o equals 0, formula (d) may be written in the form

$$\frac{L_2 - L_1}{\theta_2 - \theta_1} = -(H_m - H_o) \qquad \text{(e)}$$

PLATE N.


1/16
1/8
1/4
KNO3
1/2
CHANGE IN TEMP. WHEN MIXED °C/1000
-100
-200
-300
-400
-500
SEE PREVIOUS SHEET
0
10°
20°
30°
TEMPERATURE BEFORE MIXING °C.
-500
-600
-700
-800
-900
K N O3
1
CRYSTALS FORMED
CHANGE IN TEMP. WHEN MIXED °C/1000
0
10°
20°
30°
TEMPERATURE BEFORE MIXING °C

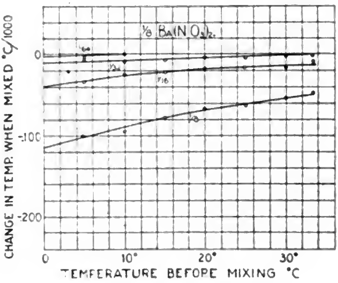
The following tables show the values of equation (e) for the several solutions tested:

Tables for Values of $\frac{L_2 - L_1}{\theta_2 - \theta_1}$ and $-(H_r-H_1)$.

NaCl. $H = 448.2$

θ_2-θ_1	200	100	50
10–4	8.5	14.0	19.2
20–10	7.0	11.8	14.9
30–20	5.7	9.8	12.1
$-(H_r-H_1)$	6.0	10.2	13.8

PLATE O.



KCl. $H = 440.3$

θ_2-θ_1	200	100	50	25
10–4	6.4	10.5	14	15.7
20–10	5.4	9.7	12.5	14
30–20	4.6	7.2	11.9	12.2
$-(H_r-H_1)$	8.3	13.1	18.1	22.2

½ $BaCl_2$. $H = 430.6$

θ_2-θ_1	200	100	50	25
24–14	6	9.7	12.2	13
33.5–25	5.2	8.2	9.7	8.9
$-(H_r-H_1)$	6.2	10	13.7	16.6

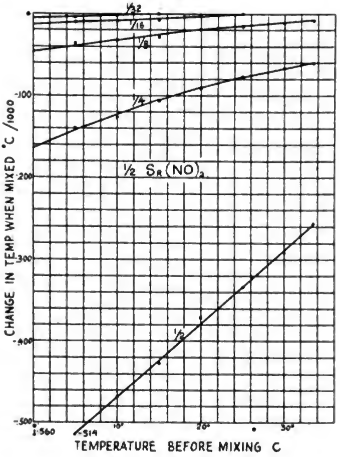
½ $SrCl_2$. $H = 430$

θ_2-θ_1	200	100	50
24–14	5.2	8.5	9.8
33.5–24	4.2	6.6	8.1
$-(H_r-H_1)$	6	10.4	15.1

NH_4Cl. $H = 445$

$\theta_2-\theta_1$	200	100	50
33.5–22	3.3	5.7	5.6
$-(H_2-H_1)$	2	4	6

PLATE P.



NaOH. (1.847) $H = 441$

$\theta_2-\theta_1$	400	200	100	50
10–5	11.6	20.4	31.0	37.4
20–10	9.8	19.3	25.4	32.1
30–20	7.8	16.6	19.6	22.6
$-(H_2-H_1)$	5.88	10.88	15.88	18.88

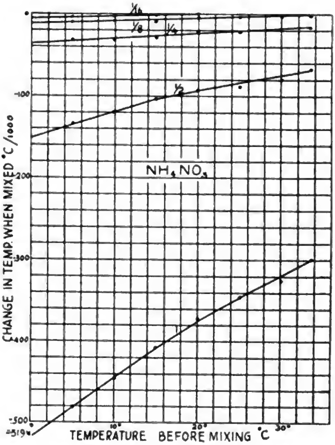
KOH. (1.645) $H = 421$

$\theta_2-\theta_1$	400	200	100	50
10–5	7.2	17	24.2	28.4
20–10	6.8	14.4	20.2	24.3
30–20	5.5	11.3	16.7	19.2
$-(H_2-H_1)$	9.4	16.4	22.4	26.4

$NaNO_3$ $H = 467$

$\theta_2-\theta_1$	200	100	50	25
10–5	11.2	16	20.8	22.8
20–10	8.4	15.2	21.3	22.2
30–20	6.8	13.6	18.8	19.4
$-(H_2-H_1)$	8.8	14.5	19.0	23.4

PLATE Q.



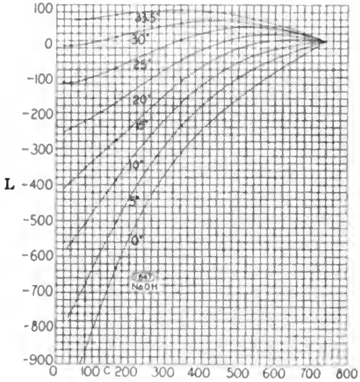
KNO_3. $H = 462$

$\theta_2-\theta_1$	200	100	50	25
10–5	10.4	24	35.2	45.2
20–10	8.8	17.2	23.8	27.4
30–20	6.8	12	16.2	17.8
$-(H_2-H_1)$	9.9	18.6	25.2	31.2

⅛ $Ba(NO_3)_2$. $H = 448.9$

$\theta_2-\theta_1$	200	100	50
10–5	2	4.2	6.8
20–10	2	3.5	5.2
30–20	1.3	2.1	3.2
$-(H_2-H_1)$	1.8	3.9	For ½ $Ba(NO_3)_2$

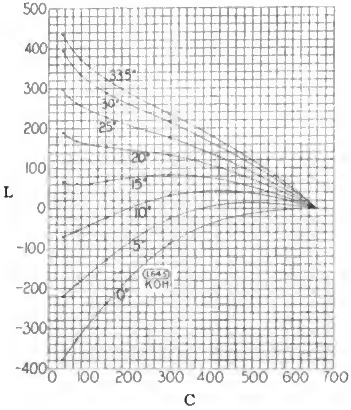
PLATE R.



½ $Sr(NO_3)_2$. $H = 452.7$

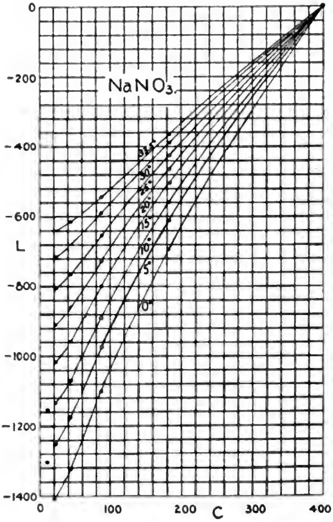
$\theta_2-\theta_1$	200	100	50
10–5	8.4	16.4	20.8
20–10	7.6	14.4	19.2
30–20	7.8	12.4	17.2
$-(H_2-H_1)$	7.7	11.7	15.0

PLATE S.



9. *Discussion of Results of Tests of Formula.*—In a general way the formula seems to hold. The values of $-(H_2-H_1)$ in KCl and $SrCl_2$ are too large, and in NaOH they are too small. The initial solution used to obtain the (L, C) curve contained 1.847 gramme-molecules of NaOH, while only one gramme-molecule was used to obtain the value for $-(H_2-H_1)$. This difference accounts for the lack of agreement in the NaOH solution, but there is no known reason for the lack of agreement in the other two.

PLATE T.



The value of $\frac{L_2-L_1}{\theta_2-\theta_1}$ in every solution decreases considerably with increase of temperature. This fact contradicts the assumption that dH/dm is a constant. The single value of $-(H_2-H_1)$ for each concentration assumes that the value does not change with the temperature. There must be a change, however, if equation (e) holds for all temperatures. Since equation (e) was found by assuming that dH/dm was constant, it is necessary to modify equation (e). It is a well-known fact that the specific heat of water decreases a small amount between 0° and 33°, and, since a large part of the system is water, the heat capacity

PLATE U.

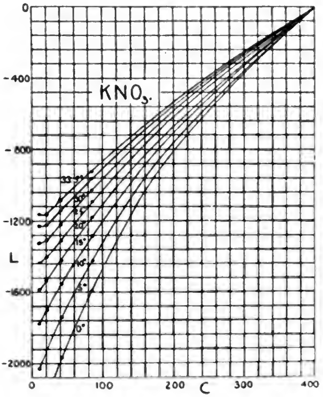
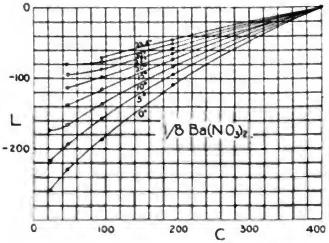


PLATE V.



must change with the temperature. Teudt has shown that the change in the heat capacity of a salt solution with change of temperature is in general less than that of water.[3]

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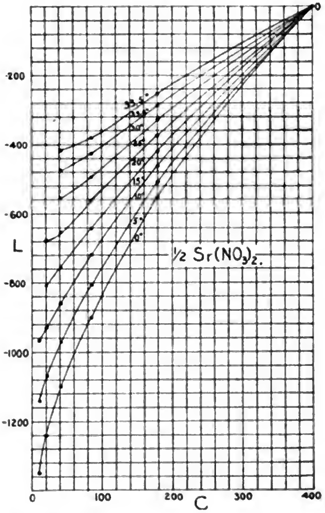
[3] Inaug. Diss. Erlangen, *Beiblatter*, xxiv, p. 1104 (1900).

The specific heats of the several salts increase with increase of temperature, hence, if the properties of a concentrated solution are additive, we may assume the specific heat of the solution to be constant, or more nearly so than water. As there is no very definite knowledge on this point, suppose we assume the specific heat of a concentrated salt solution to be constant.

PLATE W.



10. *Modification of Relations.*—When the heat capacity of the solution is assumed to be constant with respect to the temperature it is possible to derive relations which more nearly fit the experimental values. Let

M = the total mass of water in the system.
m = the mass of water in the solution.
$M-m$ = the mass of water outside of the solution.
h = the heat capacity of the solution.
S = the specific heat of the solution.
σ = the specific heat of the water outside of the solution.

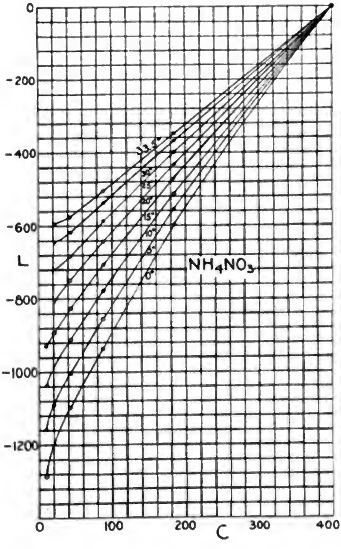
Then $H_o = Sm + \sigma (M - n)$. A small mass of water, *dm*, transferred from the supply outside of the solution, to the solution gives the heat capacity

$$H_1 = (S + \frac{dS}{dm} dm)(m + dm) + \sigma (M - m - dm)$$

and

$$H_1 - H_o = Sdm - \sigma dm + m\frac{ds}{dm} dm$$

PLATE X.



but

$$H_1 - H_o = dH$$

therefore

$$\frac{dH}{dm} = S - \sigma + m\frac{dS}{dm} \qquad \text{(f)}$$

$$h = mS \text{ and } dh = mdS + Sdm$$

therefore

$$\frac{dh}{dm} = m\,\frac{dS}{dm} + S$$

This equation, substituted in (f), gives

$$\frac{dH}{dm} = \frac{dh}{dm} - \sigma$$

This value of $\frac{dH}{dm}$, substituted in (a), gives

$$\frac{dl}{d\theta} = -\left(\frac{dh}{dm} - \sigma\right) \ldots\ldots\ldots\ldots\ldots\ldots\ldots \text{(g)}$$

By integration

$$l = -\left(\frac{dh}{dm}\right)\theta + \int \sigma\,d\theta + e$$

When this equation is integrated with respect to *m*, and θ is constant, we obtain

$$L_1 - L_o = -(h_1 h_o) - (\theta_1) + \int\!\!\int \sigma\,d\theta\,dm + edm \ldots\ldots\ldots\ldots \text{(h)}$$

or

$$= -(h_1 - h_o)(\theta_1) + (M_1 - M_o)\int \sigma d\theta + edm$$

and

$$L_2 - L_o = (h_1 - h_o)(\theta_2) + (M_1 - M_o)\int \sigma d\theta + edm \ldots\ldots\ldots\ldots \text{(i)}$$

When (h) is subtracted from (i),

$$L_2 - L_1 = (h_1 - h_o)(\theta_2 - \theta_1) + (M_1 - M_o)\int_{\theta_1}^{\theta_2} \sigma\,d\theta \ldots\ldots\ldots\ldots \text{(j)}$$

Equation (j), divided by $\theta_2 - \theta_1$, gives

$$\frac{L_2 - L_1}{\theta_2 - \theta_1} = (h_1 - h_0) + \frac{M_1 - M_0}{\theta_2 - \theta_1}\int_{\theta_1}^{\theta_2} \sigma d\theta \ldots\ldots\ldots\ldots\ldots\ldots\ldots \text{(k)}$$

The left sides of equation (k) and (e) are equal. The right side of equation (k) shows the variation of $-(H_2 - H_1)$ which must be used in the cases tested, when the change in the specific heat of water with respect to the temperature is taken into account.

The formula for the specific heat of water proposed by Callendar[4] for temperatures between 0° and 20° is

$$\sigma = 0.9982 + 0.0000045(t-40)^2 + 0.0000005(20-t)^3 \ldots\ldots\ldots\ldots (1)$$

and for temperatures between 20° and 60° the last term is omitted.

If equation (l) is multiplied by $d\theta$ and integrated between the limits θ_1 and θ_2, we have

$$\int_{\theta_1}^{\theta_2} \sigma\, d\theta = 0.9982\ (\theta_2 - \theta_1) + 0.0000045 \left\{ \frac{1}{3}\ (t_2 - 40)^3 - \frac{1}{3}\ (t_1 - 40)^3 \right\}$$

$$+ 0.0000005 \left\{ \frac{1}{4}\ (20 - t_1)^4 - \frac{1}{4}\ (20 - t_2)^4 \right\} \ldots\ldots\ldots\ldots (\mathrm{m})$$

Equation (m), substituted in equation (k), gives the complete expression which is to take the place of $-(H_2 - H_1)$.

The value of h_0 for NaCL at concentration 400 is 448.2, and for concentration 200 the value of h_1 is 892.2. The difference between these numbers is 444, which, according to the theory proposed, is constant for all temperatures. The value of the second term in the right side of equation (k) varies with the temperature. Let θ_1 and t_1 equal 4° C. and θ_2 and t_2 equal 10° C.; then the last term in equation (k) becomes 451.9. The difference between 451.9 and 444 is 7.9, which is the value of the right side of equation (k). The corresponding value of $\frac{L_2 - L_1}{\theta_2 - \theta_1}$ the left side of equation (k), is found by experiment to be 8.5. In a similar manner for temperatures 10° to 20° the right side is 6.5 and the experimental value is 7.0. For temperatures 20° to 30° the right side is 5.66 and the experimental value is 5.7. The difference between 7.9 and 5.66 is 2.2, which is the change in the left side of equation (k) between 0° and 30°. This change will be the same for all solutions at concentration 200. While it is slightly too small for the NaCl, it is about right for KCl and KOH. At concentrations 100 this difference would be doubled, or 4.4. At 50 it would be 8.8, and at 25 it would be 17.6. With the exception of KNO_3, which has a very large variation, these last numbers are too large. As the solution becomes more dilute it is highly probable that the specific heat of the solution changes similarly to water, which would tend to reduce

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[4] *Phil. Trans.* R. S. (1902), clxix, 142.

PLATE 1.

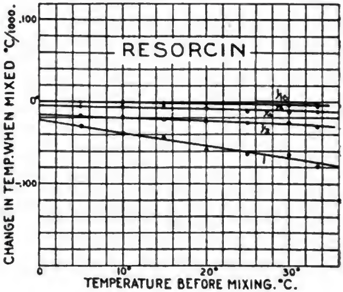


PLATE 2.

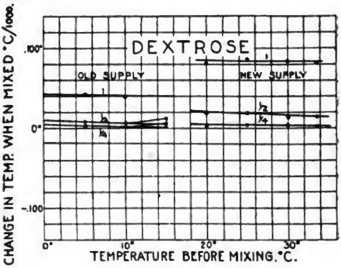


PLATE 3.

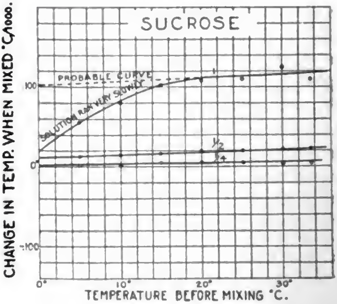
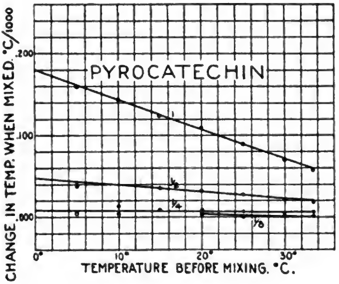


PLATE 4.



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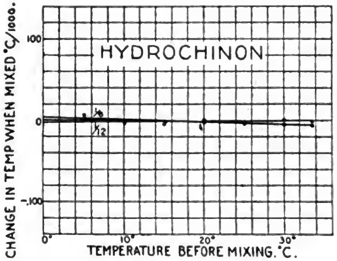


PLATE 6.

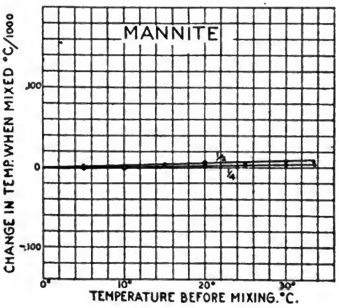


PLATE 7.

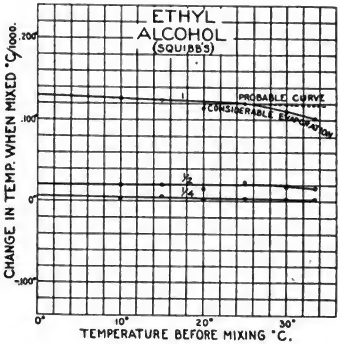


PLATE 8.

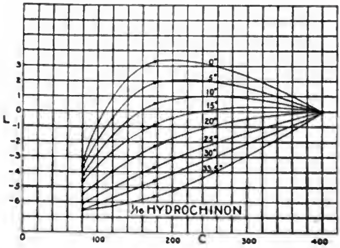


PLATE 9.

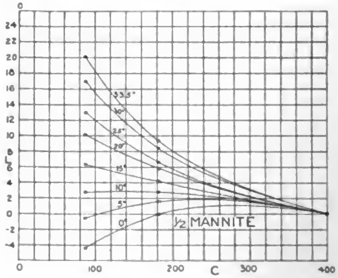


PLATE 10.

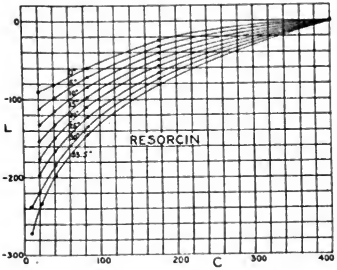


PLATE 11.

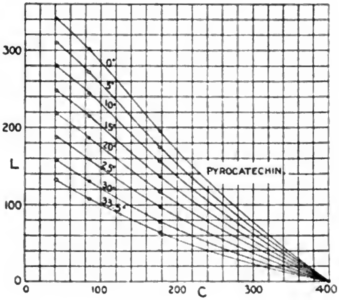


PLATE 12.

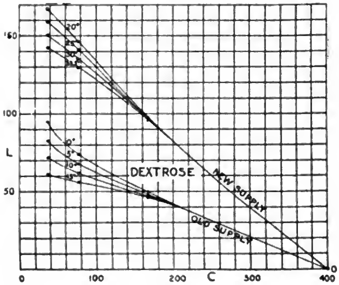


Plate 13.

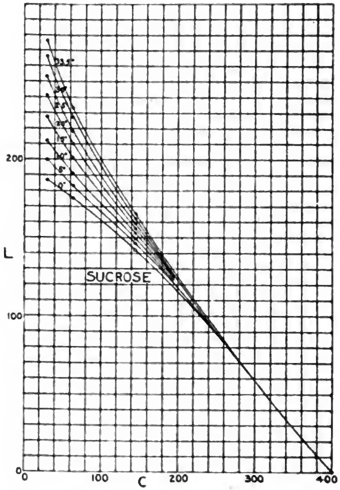
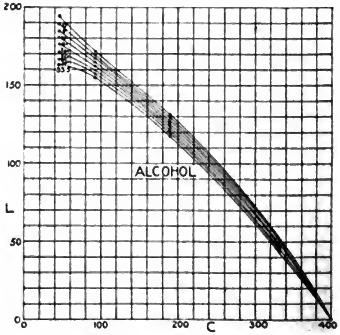


Plate 14.



these numbers at the more dilute concentrations. When the change in the specific heats with respect to temperature for all concentrations of the several solutions is definitely known it may be possible to account for all the exceptions found in these results.

11. *Heats of Dilution of Non-electrolytes.*—The point of interest with the non-electrolytes is that the H is constant for all concentrations. Equation (a) equals zero, since $\frac{dH}{dm} = a = 0$, therefore $\frac{dl}{\theta d} = 0$ and $l = c$, a constant, and should not vary with the temperature. The (L, C) curves should be parallel and the curves in Plates 1 to 7 should be horizontal straight lines. The curves in Plates 1 to 7 are straight lines, but none of them is. exactly horizontal. Resorcin and pyrocatechin show considerable variation from the horizontal, and this produces the fan-shaped (L, C) curves. If the (L, C) curves of the non-electrolytes were plotted to the same scale as the (L, C) curves of the electrolytes the lines would be very much closer together. The use of the much larger scale with several of the non-electrolytes exaggerates the small departure from the theory. It is of interest to note that, while the majority of the lines in Plates 1 to 7 slant slightly downward toward the right, there are two or three that slant upward toward the right. This proves conclusively that this slight variation was not due to any fault of the apparatus.

I take this opportunity to thank Prof. W. F. Magie for placing a room and the equipment of the Palmer Physical Laboratory at my disposal. I wish to express my appreciation of his kindly assistance and to acknowledge the many suggestions received from him and Prof. H. L. Cooke while carrying on the work.

PALMER PHYSICAL LABORATORY,
Princeton University,
June, 1917.

Pure Sheet Nickel. ANON. (*The Iron Age*, vol. 101, No. 11, p. 690, March 14, 1918.)—Pure solid nickel should not be confounded with the much inferior metals usually sold as nickel, which consist mostly of steel, brass, or German silver with a thin plating of nickel. This plating wears off in a short time, leaving manufactured articles unserviceable and worthless. Nickel is essentially an American product. For many years past it has been a general practice to use ore which has been mined in this country and Canada, having it fabricated into its various forms by European manufacturers. Previous to the war most of the material imported into this country as foreign stock was the American metal worked into the form of sheet, strip, and finished articles of manufacture by foreign concerns. Until a few years ago there had never been any appreciation of the many points of vantage of this metal for almost innumerable purposes, and consequently there had never been any adequate facilities for rolling it into large sheets.

Pure nickel does not rust or oxidize, and consequently every danger of poisoning generally caused by verdigris is eliminated. Neither will the metal tarnish like silver or some of the alloys, such as German silver, and, even though the surface be injured, there is no danger of corrosion resulting as in a plated article. Furthermore, the tedious and expensive plating operations required for articles made of other metals is entirely abolished. This makes the metal particularly adaptable for use in the manufacture of cooking utensils or food-handling equipment, where the highest precautions must always be observed to avoid infection and poisoning. This advantage of perfect safety lasts as long as the article itself, whereas plated utensils must be discarded or replated upon the appearance of the slightest break in the nickel protecting surface. While not so good a heat conductor as aluminum, nickel utensils are made of a thinner material, which more than overcomes the difference. Pure nickel has a melting-point of about 2600° F., whereas aluminum has one of about 1200°. There is not the same possibility of this metal being softened under constant use. The metal is also much more resistant to the action of the acids commonly found in food products. The fine silver-like appearance of pure nickel does not change in use, and the cleaning of these utensils is as easy and simple as possible, hot water or soda being quite sufficient.

In the chemical field there are many uses for this metal. The surface of pure nickel is not attacked by acids or alkalies in the dilute form usually encountered in ordinary service. In fact, it is practically immune to the attacks of all alkalies, regardless of their strength, and is largely resistant to the action of most acids. Nickel has a high tensile strength, and in the sheet form, being homogeneous throughout, is ductile and easily formed by spinning or stamping. No special equipment is necessary for manufacturing articles from these sheets, the same tools and metals being employed as with German silver and hard alloys. The great increase in the cost of copper and its products has brought pure nickel to a point where it can be compared with favorably as to initial cost, without counting long life and service.

AN IMPROVED PROGRESS-OF-WORK CHART.*

BY

F. J. SCHLINK, M.E.,

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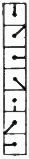
In order to supply a form of record for use in central office follow-up of important and urgent testing work, the writer developed the simple and compact type of running record chart shown herewith. It is thought that this may be of interest and value to industrial plants, and to other testing laboratories, for similar purposes.

The example given applies expressly to the recording of progress of work in a testing or investigational laboratory. As will be shown later, however, the identical principles are applicable, with the same convenience and efficacy, to following the progress of manufacturing operations. It is equally well adapted to scheduling the make-up of publications, and to recording the stage reached in the adjustment of a customer's complaint or claim.

This chart, shown in the appended figure, is practically three-dimensional in effect. The vertical coördinate defines the material tested and its references; the horizontal coördinate is that of date; while the third, which is the phase or stage of progress that the work has reached, is given by a straight line drawn in the appropriate direction in the proper date square.

A specific example of such a record is given in the illustration, in which the following actions are recorded:



Request for the test, dated	October	3
Request received	“	4
Material received	“	6
Test begun	“	6
Report prepared	“	9
Report mailed	“	10
Material reshipped	“	10

(In case the material tested is returned after completion of the work)

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* Communicated by the Bureau of Standards.

In addition we note that there was received in regard to the test

An incoming communication of October 6, followed by

An outgoing communication (in reply) of October 7

(in the case of this and the preceding record, the direction of the arrow-head on the record line indicates whether the correspondence is incoming or outgoing)

Thus each advance in the status of the work is noted by a rotation of the record mark through 45 degrees in the clockwise direction.

In case the work is followed up before completion, and a promise is given as to the date on which the report may be expected, this is indicated by a dotted line in the space corresponding to the promised date, as on October 8 in the example given. If the promised date is fulfilled, a solid line is simply drawn over the dotted line; if not, the error in the estimate is evident on the chart. When a date upon which the work should be followed up is decided upon at the time it is entered, or perhaps later when a special reason arises for so doing, this may be conveniently indicated by drawing a small circle about the central dot. When that date arrives, the horizontal diameter of the circle is drawn in, to show that the follow-up has been carried out: this is exemplified in the date space for the 7th in the example.

In the case of work carried over from one month to the next, suitable written notes are added in the vacant portions of the date ruling to avoid rewriting, on the next sheet, of data already recorded, or, if desired, the entry may be made in the usual way in a date square with the addition of the name of the month, abbreviated.

The same form can conveniently be adapted to manufacturing processes by altering the significance of the positions in which the lines are drawn. In the case of a manufacturing plant, for example, the meaning of the eight positions of the record mark may be as follows; the manner of recording will otherwise be exactly the same as described above.

1. Order dated.
2. Order received.
3. Drawings begun.
4. Drawings to shop.
5. Shop work finished.
6. Material delivered to shipping-room.
7. Material shipped.
8. Correspondence in regard to order.

In case it is desired to record more than eight stages of progress, as may be required in complicated kinds of work, other elements of the square than its diameters may be used. Eight more phases can be added by marking along the halves of the vertical and horizontal sides of the square.

The principal advantages which this method of charting affords are the following:

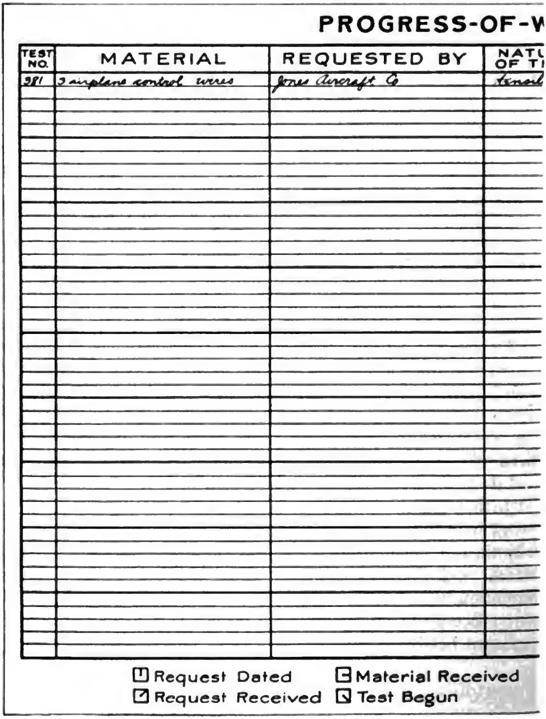
1. The whole history of the action on a given piece of work is recorded permanently.

2. The total interval required for the work is suggested at once by the distance between the initial and final lines drawn, so that the efficiencies or adequacies of the organizations of the several departments can be directly compared.

3. Instant and reliable answers can be given by the central office to inquiries received by mail or telephone.

4. Work which is not completed in proper time is readily noticed by reference to the summation column, headed Σ, so that necessary corrective action can be taken.

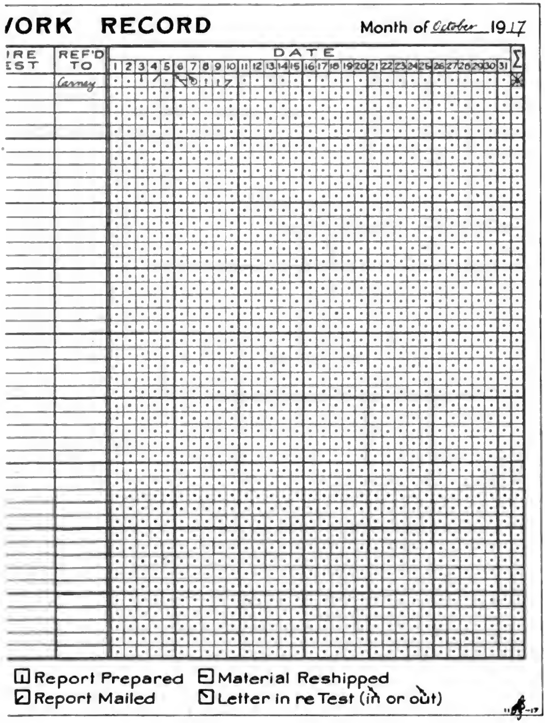
The principal advantages of this chart over the usual progress-of-work board are in the permanency of the record, which is not lost by the moving of a pin or block to the next position; its compactness; and, finally, the greater detail and definiteness of the information which it affords, making its use available to administrative officers and office employees, as well as to the foremen and department heads immediately in contact with the work.



PROGRESS-OF-W

TEST NO.	MATERIAL	REQUESTED BY	NATU OF T
381	3 airplane control wires	Jones Aircraft Co	tensil

☐ Request Dated ☐ Material Received
☐ Request Received ☐ Test Begun



/ORK RECORD Month of October 1917

IRE EST | REF'D TO | DATE 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31 | Σ

Carney

- ☐ Report Prepared
- ☐ Report Mailed
- ☐ Material Reshipped
- ☐ Letter in re Test (in or out)

A NEW THEORY OF PLATE SPRINGS.

BY

DAVID LANDAU AND PERCY H. PARR.

(JOURNAL OF THE FRANKLIN INSTITUTE, April, 1918, page 481.)

ERRATA.

Page 488, line 4, symbol should read:

$$\frac{1}{2}\, l_2$$

Page 488, lines 12 and 13:

Omit quotation marks.

Page 493, after equation (1), the line referring to Fig. 7 should read:

Now, referring to Fig. 7, it will be seen that for the n + 1th plate, we must have, for

Page 494, equation (5a) should read:

$$EI_{n+1}\delta_{n+1} = W_{n+1}\,\frac{l^3_{n+1}}{3} - W_n\left(\frac{l^2_n l_{n+1}}{2} - \frac{l^3_n}{6}\right) \qquad (5a)$$

The line following the equation should read:

Now putting n for $n + 1$ in (5a) there results:

NOTES FROM THE U. S. BUREAU OF STANDARDS.*

RADIO INSTRUMENTS AND MEASUREMENTS.

THE Bureau of Standards has issued a treatise on radio measurements,[1] for use by government officers, radio engineers, and others concerned. The circular includes a development of the essential theory of high-frequency measurements from simple but precise low-frequency theory, the use of reactance curves in the rapid solution of problems, descriptions of radio instruments, and formulas and data for radio work. The full treatment of fundamental principles will make this circular serve as a foundation for later publications which may be issued by the Bureau on the general subject of radio communication.

STABILIZED-PLATFORM WEIGHING SCALE OF NOVEL DESIGN.[2]

[ABSTRACT.]

THIS paper treats of the principles and design of a new type of weighing scale of the general class technically known as the check stabilized-platform scale. The usual stabilizing element consisting of a pin-and-link connection is replaced by a flexible elastic tape, band, or wire. This design has the important effect of eliminating practically all of the friction inherent in existing stabilizing mechanisms, with the result that the friction of stabilized-platform scales made in accordance with this new design becomes practically unaffected by the position of the load on the platform and is reduced to a very small amount. The arrangement is such that the stabilizing element is continuously under tensile stress; this being the case, the function of that link is then satisfactorily fulfilled by a flexible connector, such as a tape or band.

In the paper the earlier types of stabilizing elements are illustrated and the limitations of each set forth. The theoretical considerations underlying the conditions of equilibrium in weighing scales of the stabilized-platform type are defined and the methods used in carrying out the adjustment of such a scale are outlined. A discussion of the effects of static friction on the indications of scales is included, and the effect of the elimination of this friction in enhancing the accuracy of weighing is shown. The paper includes nearly a score of illustrations of weighing scales and scale details.

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* Communicated by the Director.

[1] Circular No. 74.

[2] Technologic Paper No. 106.

RESONANCE AND IONIZATION POTENTIALS FOR ELECTRONS IN CADMIUM VAPOR.[3]

[ABSTRACT.]

The object of this investigation has been the determination of the resonance and ionization potentials for electrons in cadmium vapor. Resonance collision of the electron with the atom was observed at 3.88 volts, and inelastic impact resulting in ionization was observed at 8.92 volts. The single line spectrum of cadmium is $\lambda = 3260.17$ Å. If we substitute the frequency corresponding to this wave-length in the relation $h^{\nu} = eV$ where $h = 6.56.10^{-27}$ erg.-sec., e the electronic charge, and V the resonance potential, we obtain $V = 3.79$ volts, in good agreement with the above. On the basis of Bohr's theory, the ionization potential should be 8.97, in most excellent agreement with the experimentally determined value.

THE APPLICATION OF DICYANIN TO STELLAR SPECTROSCOPY.[4]

[ABSTRACT.]

The Bureau of Standards has had considerable success in photographing extreme red and infra-red radiations by means of commercial plates sensitized with dicyanin. This article describes the application of such plates to stellar spectroscopy. The observations were carried out at the Harvard College Observatory, using the 24-inch reflecting telescope and objective prism. Fraunhofer's A band (wave-length 0.760μ) and a considerable region of greater wave-length were photographed in numerous stellar spectra. Several new absorption flutings were discovered, the most striking beginning at 0.760μ, nearly coincident with A, and running toward the red. Circumstances indicated that this band might be due to titanium oxide, and experiments since made at the Bureau of Standards have shown a band in this position in the spectrum of the titanium arc. The greatest wave-lengths observed in stellar spectra appear, by extrapolation, to be about 0.87μ. The general conclusions arrived at are as follows:

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[3] Scientific Paper No. 317.

[4] Scientific Paper No. 318.

1. Many stellar spectra possess sufficient intensity in the region of wave-length 0.80μ to enable this portion of the spectrum to be photographed on plates sensitized with dicyanin.

2. In favorable instances stellar spectra can be well observed to wave-length 0.85μ.

3. The region of greater wave-length than 0.70μ contains features of importance, especially in the case of the later spectral types.

A Single-lens Telescope. ANON. (*The Optical Journal and Review*, vol. 41, No. 13, p. 868, March 21, 1918.)—The first telescope invented, several hundred years ago, consisted of two lenses, a convex lens for the objective and a minus lens for the eye-piece. We still have this form of telescope in use, but it is now made binocular; that is, the ordinary opera-glass or field-glass. The magnifying power of such an instrument would be the same if it consisted of one tube and not two. In fact, we can take two lenses from a trial case, one plus the other minus, and hold them at the proper distance so as to have a telescope in its simplest form. When the eye of the observer is hypermetropic it is possible to obtain a magnifying effect similar to that produced by a telescope, by means of a single lens.

The eye of a person, hypermetropic (farsighted) 1.50 D. (diopters), will be optically similar to that of an emmetrope (person with normal vision) wearing a minus 1.50 D. sphere. Therefore, if we select a suitable plus sphere and hold it out at the right distance in front of the uncorrected eye there should be a magnifying effect, and there is. Should a plus 0.75 D. sphere be used in this way, and held at a distance of 26 inches from the eye, there will be magnification of two times. If the hypermetropia is higher than 1.50 D., the magnification will be higher; also, if the low-power plus lens used as an objective is hung up in some convenient manner, a lower power can be used, the observer takes his position farther away, and there will be a greater magnification. Some years ago an amateur yachtsman, who had a hypermetropic error of 2 D., hung a large lens of low power in his club window, and then, by taking a comfortable position a few feet back of the lens, he could see the boats sailing by under a magnification of three or four diameters, and in perfect focus.

Nature of "Rice Polish." ANON. (*Weekly Bulletin Trade and Technical Press Section,* U. S. Food Administration, vol. 1, No. 31, p. 5, March 23, 1918).—"Rice polish" is a comparatively new cereal substitute, being the waste which comes from the rice in the polishing process whereby the outer layers of the grain, containing phosphorus, are removed. Formerly this rice polish was sold by the ton for stock food, but Miss Rona K. Armstrong, of the United States Department of Agriculture, visiting New Orleans, discovered it and had it placed on the market for making conservation bread in proportions of one-fourth rice polish to three-fourths wheat flour. The *Flour and Grain World* describes methods of cleaning and polishing rice whereby this product is obtained. Rough rice from the thrashing machine is first separated from thrash, the hulls or chaff removed by rapidly revolving millstones, and the outer skin of the grain then removed by pounding in huge mortars, which gives a mixture of clean rice, fine chaff, and flour. The rice is then polished by friction against moose hide or sheepskin, tanned and worked to a high degree of softness, where the outer layers of the grain are moved, yielding rice polish, which is said to contain the most nutritive portions of the grain.

Effect of Artificial Light on the Growth and Ripening of Plants. J. L. R. HAYDEN and C. P. STEINMETZ. (*General Electric Review,* vol. 21, No. 3, p. 232, March, 1918.)—Of the thousand-and-one uses of the electric light, one of the most unique is its application to stimulate plant growth and fruition. To determine how much the growth and ripening of plants is thus stimulated, an investigation was conducted on the growth of beans in a greenhouse under electric illumination as compared with their development under natural light. The investigation was made on beans, as the natural life of the bean plant is relatively short, and it was therefore possible to get results in a reasonably short time. Gas-filled Mazda lamps were used, as previous experiments in Doctor Steinmetz's laboratory had shown that the quality of light from this type of lamp is very efficient in its action on plant growth.

A piece of ground 5 feet by 9 feet, having good black soil, was illuminated by five 500-watt lamps consuming 2.5 kilowatts. As a check test, the same kind of beans were planted in a box 36 inches square, with the same soil, under natural light. Under the influence of intense artificial illumination the fruit ripened in a little more than half the time required under daylight alone, and the saving in time is about equal to that during which the intense illumination is maintained. Although it is not profitable to raise such relatively cheap products as string beans by artificial light, such use of light for raising plants may be justified where the electric current is generated as a by-product of the heating plant, but at the cost of purchased power it would be economically justified only for temporary use with plants which have a market value only at a definite time.

NOTES FROM NELA RESEARCH LABORATORY.*

ATOMIC HEATS OF TUNGSTEN AND OF CARBON AT INCANDESCENT TEMPERATURES.

By A. G. Worthing.

Of late years great interest has been manifested in the question of atomic heats, particularly at very low temperatures, because of the great success of theories based on the quantum hypothesis in explaining quantitatively the variations which have been found. These theories generally tend toward a value of 5.95 $\frac{\text{calories}}{\text{gram-atom degree}}$ as the upper limiting value for the atomic heat of a solid under the condition of constant volume. Several substances, however, have been shown to possess greater atomic heats even at temperatures ranging from room temperature up to 700° C. or 800° C. Modifications of theory have been offered to explain these excess values, but none that are quantitative in character. Tungsten, as a material which reaches the 5.95 $\frac{\text{calories}}{\text{gram-atom degree}}$ value at ordinary temperatures, offers exceptionally favorable opportunities for the investigation of these characteristics at high temperatures.

In the present investigation the materials investigated have been in the form of uniform filaments mounted in evacuated bulbs. Due regard being paid to end losses, we have the following operating condition for a uniformly heated filament

$$IV = f(T) + C_p\, m \frac{dT}{dt},$$

in which I represents current, V voltage, T temperature, C_p specific heat, m mass, and t time. The equation states that the rate of supply of energy to the filament is equal to the sum of the rate of radiation of energy by the filament and the rate of storing up of energy in the filament. Evidently the equation applies to a cooling as well as to a heating change.

For convenience the above equation may be rewritten as

$$IV = F(R) + C_p\, m \frac{dT}{dR} \frac{dR}{dt}$$

in which R represents resistance. This assumes that, during changes of temperature, the temperature and the rate of radiation are single valued functions of the resistance. Granted this assumption, the experimental work consists mainly in determining I and V as function of t for certain definite temperature changes. This has been done with the aid of a pendulum apparatus and a potentiometer outfit, using the successive trial method. As the pendulum swung from its initial position, it operated switches which first changed the resistance in the circuit containing the filament and then, after a fixed interval, closed momentarily a galvanometer circuit showing the correctness or deviation therefrom of the potentiometer setting for the voltage or current. Successive determinations for various intervals gave I and V as functions of t. From these there follows R as a function of t. $F(T)$ represents steady state wattages. T as a function of R follows from temperature calibrations.

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* Communicated by the Director.

For tungsten the results by the cooling method show certain deviations from those obtained using the heating method. This seems to indicate that the assumption of the temperature and wattage being single valued functions of the resistance is not fulfilled. This is not considered definitely proved, however. Taking the results as a whole, the atomic heats under constant volume are fairly well represented by a straight-line relation consistent with $6.25 \frac{\text{calories}}{\text{gram-atom degree}}$ at 1200° K and $7.35 \frac{\text{calories}}{\text{gram-atom degree}}$ at 2400° K. These are considerably in excess of the supposed limiting value $5.95 \frac{\text{calories}}{\text{gram-atom degree}}$. Suggestions which have been advanced in explanation of this fact, when considered quantitatively and theoretically, are not found satisfactory.

The results for carbon were not as carefully obtained. They show an approximate linear relationship consistent with $5.35 \frac{\text{calories}}{\text{gram-atom degree}}$ at 1200° K. and $6.05 \frac{\text{calories}}{\text{gram-atom degree}}$ at 2000° K. for the atomic heat under constant pressure. When corrections are made to the condition of constant volume, these results will possibly be in accord with $5.95 \frac{\text{calories}}{\text{gram-atom degree}}$ as an upper limit. As they stand they are in very good agreement with Weber's results on diamond and graphite at ordinary temperatures and of Magnus's conclusions regarding Weber's data on the same materials at higher temperatures.

THE VISIBILITY OF RADIATION IN THE BLUE END OF THE SPECTRUM.

By L. W. Hartman.

THE determination of the visibility of radiation in the short wave-length region of the spectrum is difficult, owing principally to the small amount of light available when using ordinary methods and sources. The optical pyrometer method, which had previously been employed[1] in obtaining this function for the red end of the spectrum, minimizes this difficulty, and has now been used to obtain values of the visibility in the blue end out as far as wave-length 0.400μ. In contrast to results obtained by the flicker photometer, this method involves the direct-comparison principle.

The effect of stray light and of extreme color-difference was eliminated to a very large extent by the use of a piece of blue glass, of known spectral transmission, in the eyepiece of the telescope. During any one run the brightness was kept constant, but experiments were also made with values of brightnesses as seen through the blue glass ranging from 0.000033 to 0.0013 candle per square centimetre. A small field was employed, and tests indicated no evidence of a Purkinjé effect. Corrections were made for slit-widths, for the dispersion and selective absorption of the prism and lens system, for scattered light, and for the absorption of the blue glass.

Measurements were made by twenty observers, all of whom were trained in laboratory work. The results, together with the published data of other investigations are given in the table.

Wave-lengths, $\mu\mu$	Mean visibility of twenty subjects	Mean values given by Nutting*	Mean values given by Coblenz and Emerson
410	1.7	9.5	24
420	11.4	17.1	42
430	32.6	30.3	59
440	61.6	58.0	71
450	100	100	100
460	153	168	137
470	240	266	202
480	376	392	305
490	620	566	474
500	905	828	770

*These values, kindly furnished by Doctor Nutting, differ slightly from his published data, owing to the redetermination of the distribution of energy in the spectrum of the acetylene flame used.

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[1] *Astrophys. Jour.*, vol. 42, 1915, p. 285.

EFFECT OF HYDROGEN ON THE ELECTRICAL RESISTIVITY OF CARBON.

By T. Peczalski.

THE effect of hydrogen on the electrical resistivity of carbon has been studied at different temperatures and pressures. It has been found:

1. That hydrogen apparently produces no effect on the resistivity at ordinary temperatures for pressures up to 33 atmospheres.

2. That the resistance of carbon increases considerably when the filament is heated to a high temperature in hydrogen.

3. That the resistance at room temperatures following such a heating in hydrogen shows a similar and more marked increase.

4. That subsequent heating of the filament in vacuum to the same temperature produces the opposite effects.

5. That the effect is greater for the higher pressures than for the lower pressures.

6. That these changes are suggestive of an exponential law and are about equal in magnitude in cases where the filaments are not injured appreciably by the processes involved.

The Doretype—a De Luxe Style of Portrait Photograph. ANON. (*The British Journal of Photography,* vol. 65, No. 3009, p. 4, January 4, 1918.)—A new style of portrait photograph, the Doretype, has recently been introduced through the Eastman School of Professional Photography, as a means of providing a form of portrait photograph of rich distinctive appearance, yet capable of being produced at a comparatively low cost. The Doretype is a warm-toned, thin, positive image on glass, and receives its brilliancy from the material which is used as a backing. It lends itself to almost any treatment. It may be backed with light-tinted papers, or various shades of fine silk or satin, but the most satisfactory method is to coat the back of the transparency with a fine gold bronze.

With edges simply bound or the picture mounted in a frame, most of the attractiveness of the Doretype is lost. The aim of the promoters has evidently been to originate something which in its way can be prized by the possessor just as the daguerreotype miniatures were prized in their day. The new process is not one that can be entrusted to an indifferently skilled operative, but calls for a high degree of skill in the making of the glass transparency, and, like the daguerreotype, needs a fitting setting to show it to the best advantage.

NOTES FROM THE RESEARCH LABORATORY. EASTMAN KODAK COMPANY.*

THE VISIBILITY OF RADIATION.[1]

By Prentice Reeves.

[ABSTRACT.]

THIS experiment was performed to obtain more data on the subject by using a method similar to that used by Ives[2] and Nutting.[3] The values for the spectral energy distribution of acetylene were those offered by Nutting and two values offered by Coblentz. The data obtained by using the different acetylene energy values enable one to compare results with the other experiments, as well as to show the effect of using the values with the same data.

The apparatus used was a modification of the Nutting monochromatic colorimeter. The light from a standard acetylene burner passes through a pair of Nicol prisms and a collimating lens to a constant deviation dispersing prism which is operated by a screw carrying a direct-reading wave-length drum and then to the observer's eye. By means of a Whitman disk the light from a gas-filled tungsten lamp which passes through a daylight filter is intermittently mixed with the monochromatic light, and a flicker balance is made by varying the intensity of the colored light. With both light-sources constant and three independent series taken on different days it is safe to assume that the resultant average for each of the thirteen observers is representative.

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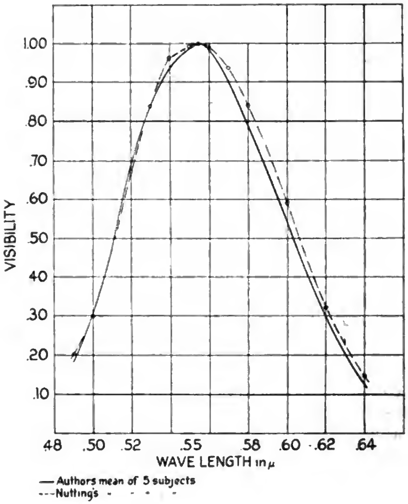
* Communicated by the Director.

[1] Communication No. 55 from the Research Laboratory of the Eastman Kodak Company, published in *Trans. Illuminating Engineering Society*, February, 1918, p. 101.

[2] H. E. Ives, *Phil. Mag.*, 1912, **24**, p. 149.

[3] P. G. Nutting, *Phil. Mag.*, 1915, **29**, p. 301; *Trans. Illum. Eng. Soc.*, 1914, **9**, p. 633.

Five of the observers in the experiment were also observers in Nutting's experiment, and the figure shows the mean of the writer's results and Nutting's results from these five observers treated separately. For these observers the average maximum visibility found by the writer is 0.555 and by Nutting 0.554.



The table shows the writer's data obtained from all observers when using the different acetylene results, the means obtained by Nutting and Ives, and visibility as computed from Nutting's formula

$$V = Vm\ R^{a}\ e^{a\ (l-R)}$$

where $R = \lambda$ max 1λ and $a = 181$. The maximum visibility obtained from the thirteen observers is at wave-length 0.553 in agreement with Ives, as against 0.555 from Nutting's results.

Table of Comparative Visibility Results.

Wave-length	Mean V from 13 subjects	Coblentz data pub. 1911	Coblentz data pub. 1916	Nutting's mean	Ives's mean	Computed from formula
0.49	0.175	0.172	0.172	0.237	0.235	0.232
0.50	0.289	0.283	0.275	0.330	0.363	0.358
0.51	0.475	0.471	0.474	0.477	0.596	0.514
0.52	0.702	0.705	0.686	0.671	0.794	0.675
0.53	0.842	0.851	0.841	0.835	0.912	0.824
0.54	0.950	0.947	0.935	0.944	0.977	0.933
0.55	0.990	0.988	0.993	0.995	1.000	0.994
0.56	0.977	0.982	0.985	0.993	0.990	0.993
0.57	0.898	0.926	0.935	0.944	0.948	0.939
0.58	0.807	0.825	0.836	0.851	0.875	0.839
0.59	0.676	0.693	0.710	0.735	0.763	0.717
0.60	0.548	0.552	0.580	0.605	0.635	0.585
0.61	0.409	0.417	0.446	0.468	0.509	0.456
0.62	0.293	0.294	0.319	0.342	0.387	0.343
0.63	0.194	0.185	0.214	0.247	0.272	0.235
0.64	0.127	0.125	0.140	0.163	0.175	0.158

Degrees of Permanence in Photographic Prints. ANON. (*The British Journal of Photography*, vol. 65, No. 3015, February 15, 1918.)—Within ten or fifteen years ago a photograph by a "permanent" process meant one by either the platinum or carbon process. There is a very good reason why it had this signification, for during the twenty-five or thirty years during which albuminized paper was the printing method in universal use carbon and platinum prints were the only two forms of photograph which could be said to have established themselves as yielding prints of unquestioned permanence, and in this respect were distinguished from the ordinary silver prints, with their liability, particularly in later years, to fade. Opinions will differ as to what constitutes permanence, but such a formula is that no marked alteration will be observable in prints when kept under reasonable conditions for a period of, say, twenty years. This definition refers to prints belonging to the vast majority classed as portraits, views, etc. Obviously twenty years would be much too short a time for prints in which permanence is a prime consideration; such prints would be expected to last for fifty or a hundred years. Leaving carbon and platinum out of consideration, there can be no doubt that the most permanent form of photograph among the papers available at the present time is that on a bromide or gaslight paper. Such a print, if properly made and mounted, and preserved under suitable conditions, should meet the permanence requirement of twenty years' life. The effect of time upon it when mounted and framed should never be more than a slight yellowing of the whites, and need not necessarily be that.

Nomography. F. L. MARTINEAU and A. M. ARTER. (*Proceedings of the Institution of Automobile Engineers,* March, 1918.)—There is probably no device of mathematical analysis that has proved so great an aid to progress in every branch of technology as the graphic diagram in rectangular coördinates. Although other methods of graphically representing functions and variables have been developed, for the majority of applications the rectangular system, as may be judged by its widespread use, has proved preferable. Works on analytic geometry are generally restricted to a discussion of the rectangular and the extensively though less used polar systems. Among other methods of graphically representing variable quantities that have been developed in recent years, the system known variously as "nomography," "alignment charts," and "parallel coordinates" has come into use, and is proving an important labor-saving device in graphic calculations better adapted to the purpose than the coördinate diagram.

This system is based upon the use of parallel axes upon which values of the variables are graduated. A simple form of a chart of this kind is represented by thermometer scales with adjacent graduations in Centigrade and Fahrenheit. With three variables there are three separate parallel lines. From these the required value of the function is determined by the intersection of a transversal passing through the two known values of the variables marked on the adjacent parallels. Under certain conditions one and sometimes all of these lines become curved. The advantage of the nomographic diagram is apparent when a two-variable equation with a variable parameter is considered. With the rectangular system a series of curves must be constructed for different values of the parameter, and interpolations with such a diagram are uncertain. The nomogram, on the other hand, consists of only three graduated lines from which values are easily read or interpolated.

The system was first introduced by M. d'Ocagne, of the École Polytechnique, in Paris, in or about the year 1884. For a study of the subject the following works may be consulted: "Alinement Charts," E. S. Andrews, 1917; "Graphs and Abacuses," R. de Beaurepaire, Madras, 1907; "The Use of Nomograms in the Determination of Thermal Efficiency of Internal-combustion Engines," W. J. Goudie, *Proceedings Inst. Engineers and Shipbuilders in Scotland,* 1916–17; "Nomography, or the Graphic Representation of Formulæ," Royal Artillery Institution, 1913; "Traité de Nomographie," M. d'Ocagne, Paris, 1899; "Calcul Graphique et Nomographie," M. d'Ocagne, Paris, 1914 (the latter work contains a complete bibliography of French works on the subject); "The Construction of Graphical Charts," John B. Peddle, New York, 1910; "Graphical Methods," C. Runge, New York, 1912.

THE FRANKLIN INSTITUTE.

(Proceedings of the Stated Meeting held Wednesday, April 17, 1918.)

HALL OF THE FRANKLIN INSTITUTE,
PHILADELPHIA, April 17, 1918.

PRESIDENT DR. WALTON CLARK *in the Chair.*

Additions to membership since last report, 2.

Reports of progress were presented by the Committee on Science and the Arts and the Committee on Library.

The Chairman then introduced Lieut.-Col. Allerton S. Cushman, Ph.D., Ordnance Department, N. A., formerly Director of the Institute of Industrial Research, Washington, D. C., who presented a communication, entitled "Growing of Medicinal Plants in America." The speaker referred to such plants as stramonium, belladonna, aconite, digitalis, etc., from which substances used as medicines are extracted. Prior to the present war the medicinal herbs were imported from European or Asiatic countries, many of them controlled by the Central Powers. The higher cost of labor in the United States had not made it possible to undertake the large-scale production of these as regular crops. The speaker and his associates have since attempted the production of temperate-zone medicinal plants, especially belladonna, with a view to meeting the demand of our home markets. It was found necessary in this undertaking to devise some special forms of machinery for planting and other purposes, and these were fully described. The various steps in the care and handling of the plants, from the seeds to the final transplanting in the open field, were outlined as well as the steps taken to protect them against insects and other destructive agents.

A moving picture of the propagation and care of some of these medicinal plants was shown.

After a brief discussion, the thanks of the meeting were extended to Colonel Cushman.

Adjourned.

GEORGE A. HOADLEY,
Acting Secretary.

MEMBERS OF THE FRANKLIN INSTITUTE WHO ARE IN THE ACTIVE MILITARY OR NAVAL SERVICE OF THE UNITED STATES GOVERNMENT.

Name and rank	Branch of service	Location
Abbott, A. C., Lieut.-Col.	Greenleaf School of Military Hygiene	Chickamauga Park, Ga.
Allen, Henry B., 1st Lieut.	Ordnance Dept., U. S. R.	France
Anderson, Geo. L., Colonel	Board of Ordnance & Fortification	Washington
Atherholt, Gordon Meade	Aeronautical Mechanical Engineer, Signal Corps	Washington
Atterbury, W. W., Brig. Gen.	Director-General of Railways	France
Bacon, Raymond Foss, Lt. Col.	Head of Chemical Service Section, U.S.N.A.	France
Barnhart, G. Edw.	Aeronautical Mechanical Engineer, Signal Corps	Fairfield, Ohio
Barr, John H., Major	Ordnance Reserve Corps	Washington
Barrett, C. D., Major	9th Engineers	
Bartow, Edward, Major	U.S.N.A. Sanitary Corps	France
Booz, Horace Corey, Colonel	Railroad Transportation Corps, U.S.N.A.	France
Bostwick, John Vaughan, Capt.	O.R.C., 315th Infantry	Camp Meade
Breed, George, Lieutenant	Fleet Naval Reserve, U.S.N. R.F.	New York
Bunting, C. M., Colonel	E.O.R.C., U.S.A.	France
Cadwalader, Governeur, Major	Ordnance Dept., U.S.R.	
Caldwell, E. W.	Medical Officers' Reserve Corps	
Capps, W. L., Rear Admiral	Chief Constructor, U.S.N., Bureau of Construction and Repair	Washington
Carty, John J., Colonel	Signal Corps, U.S.A.	
Chance, Edwin M., Capt.	Ordnance Dept., U.S.R.	Washington
Clark, Beauvais, Sergeant	108th Field Artillery	Camp Hancock
Clark, E. L., 1st Lieut.	Signal Corps, 401st Telegraph Battalion	Camp Devens
Clark, Theobald F., Capt.	Field Artillery	Fort Sill
Clark, Walton, Jr., Capt.	Field Artillery	Fort Sill
Cornelius, John C., 1st Lieut.	Coast Artillery, U.S.N.A., 13th Company	Sandy Hook
Cottrell, Jas. W., Private	Instruction Section, Ordnance Dept., U.S.A.	Peoria, Ill.
Cowan, Henry B., Sergeant, 1st Class	Co. D., First Telegraph Battalion, Signal Reserve Corps	France
Crampton, George S., Major	Director of Field Hospitals, 28th Div.	Camp Hancock
Cushman, A. S., Lieut. Col.	Ordnance Dept., U.S.N.A.	Frankford Arsenal
Detwiler, Jas. G., 1st Lieut.	Infantry, U.S.R.	Fort Logan H. Roots
Eckert, S. B., Lieut.	Commander 9th Aero Squadron	France
Elliott, Henry M., 1st Lieut.	Ordnance Dept., U.S.R.	Western Cartridge Co.
Emerson, Geo. H., Colonel	In charge of Russian Railway Service Corps	Japan
Felton, Samuel M.	U. S. Director-General of Railways in connection with Expeditionary Force	Chicago

Name and rank	Branch of service	Location
Ferguson, Walter B., Private	21st Co., 154th Depot Brigade	Camp Meade
Fraser, Persifor, Ensign	U.S.N.R.F.	League Island
Gardner, H. A., Senior Lieut.	Naval Flying Corps	Washington
Gfrörer, A. H., 1st Lieut.	Ordnance Dept., U.S.R.	Washington
Gibbons, Joseph E., Private	Co. D., 103rd Engineers	Camp Hancock
Gillmor, R. E., Senior Lieut.	U. S. Navy	New York
Glendinning, Robt. E., Major	Aviation Section, Signal Corps	Overseas
Goodwin, Harold, Jr., Lieut.	Naval Reserve Force	Philadelphia
Gribbel, W. G., Captain	Co. A., 30th Engineers, U.S.R. (Gas and Flame)	France
Griest, Thos. S., 1st Lieut.	1st Telegraph Battalion, Signal Corps, U.S.A.	France
Hall, R. T., Rear Admiral	U. S. Navy, Inspector of Machinery	Cramps' Shipyard
Hodges, Austin L., Capt.	Ordnance Dept., U.S.R., Experimental Officer on Artillery Ammunition	Frankford Arsenal
Howson, Richard, Sergeant	306th Ambulance Corps	Camp Meade
Ives, H. E., Captain	Signal Corps, U.S.A.	Washington
Jones, Jonathan, Captain	E.O.R.C., 23rd Engineers	Camp Laurel
Karrer, Enoch, Private	45th Engineers, Company A	Camp Meade
Kennedy, M. C., Colonel	Deputy Director General of Transportation	France
Kent, S. Leonard, Jr., 2nd Lieut.	5th Engineers	Camp Lee
Kingsbury, E. F., 1st Lieut.	Aviation Section, S.O.R.C., Dept. of Science and Research	Washington
LeBoutillier, H. W., Private	Unit No. 10, Pennsylvania Hospital	France
Lichtenberg, Chester, 1st Lieut.	Engineer Reserve Corps, U.S.A.	Washington
Longstreth, Chas., Lt. Commander	U.S.N.R.F.	Philadelphia
McCoy, John F.	Aviation Section, Signal Corps	Princeton
MacLean, Malcolm R., Major	Infantry R. C.	Camp Meade
McMeekin, C. W., Major	Army War College	Washington
Martin, Thos. S., 1st Lieut.	Ordnance Dept., U.S.R.	Washington
Masters, Frank M., Major	Ordnance Dept., U.S.R.	Washington
Maxfield, H. H., Lieut. Col.	19th Railway Engineers, U.S.N.A.	
Mershon, Ralph D., Major	E.O.R.C., U.S.A.	New York
Miller, Fred. J., Major	Ordnance Reserve Corps	Centre Bridge, Penna.
Owens, R. B., Major	Signal Corps	France
Parrish, T. R., 1st Lieut.	Signal Corps	Washington
Reber, Samuel, Colonel	Signal Corps, U.S.A.	New York
Richardson, Chas. E., 1st Lieut.	30th Engineers, U.S.R. (Gas and Flame)	France
Spackman, Henry S., Major	Engineer Officers' Reserve Corps	France
Spruance, W. C., Jr., Lt. Col.	Ordnance Dept., National Army	Chevy Chase, Md.
Squier, Geo. O., Major General	Chief Signal Officer, U.S.A.	
Stanford, H. R., Civil Engineer	U. S. Navy	Boston
Thomas, Geo. C., Jr., Captain	Aero Service Squadron 96, Aviation Section, Signal Corps	France
Tilghman, B. C., Captain	A.D.C., 28th Div. Headquarters, U.S.A.	
Vogleson, J. A., Major	Camp Jas. E. Johnston	Jacksonville, Fla.
Wagner, Fred. H., Major	Ordnance Reserve Corps, Nitrate Division	Washington

Name and rank	Branch of service	Location
Wagner, Fred. H., Jr. Sergeant	Co. E., 304th Engineers	Camp Meade
Wetherill, W. C., Ensign	U. S. Navy	
Widdicombe, R. A., Major	C.Q.M., Chemical Plant No. 4	Saltville, Va.
Wood, Edw. R., Jr., Captain	18th Field Artillery, U.S.N.A.	El Paso, Texas
Worrell, Howard Sellers	3rd Officers' Training Camp	Fortress Monroe
Wyckoff, A. B., Lieut.	U. S. Navy	Ontario, Cal.
Yale, A. W. Major	Medical Reserve Corps, Gas Division	Camp Kearney
Yorke, George M., Major	Signal Corps, U.S.R.	New York

MEMBERS DOING CIVILIAN WORK FOR THE UNITED STATES GOVERNMENT

Name	Appointment	Location
Akeley, Carl E.	Consulting Expert of Mechanical Devices, War Department	Washington
Anderson, Robt. J.	Engineer of Tests of Ordnance, War Dept., U.S.A.	Brier Hill Steel Co.
Balls, William H.	Ships Draughtsman	Phila. Navy Yard
Bancroft, Joseph	Secretary, Local Board No. 1	Wilmington
Baskerville, Charles	Working with Bureau of Mines, Ordnance Dept. (Gas Warfare, Shells, etc.)	New York
Bodine, Samuel T.	Vice-Chairman, District Exemption Board, No. 1, Eastern Judicial District of Penna.	Philadelphia
Brown, Lucius P.	Federal Milk Commission	New York
Burnham, George, Jr.	Dept. of Civilian Service and Relief, Public Safety Committee of Pennsylvania	Philadelphia
Charles, Bernard S.	Ordnance Inspector, U. S. Navy	Allentown, Pa.
Comey, Arthur M.	Chairman, Sub-Committee on Explosives, Chemistry Committee, National Research Council	Chester, Pa.
Condict, G. Herbert	Naval Consulting Board, Member Committee of Examiners	Plainfield, N. J.
Cooke, Morris L.	Chairman, Storage Committee of Munitions Board; Member on Staff, Emergency Fleet Corporation	Washington
Cope, Thomas D.	National Research Council	Washington
Day, Charles	Member of Army War Council	Washington
Delano, Frederic A.	Member of Federal Reserve Board	Washington
Dickie, G. W.	Chief Inspector, U. S. Shipping Board, Moore & Scott Shipyard	Oakland, Calif.
Dunn, Gano	Chairman, Engineering Committee, National Research Council	New York
Garrison, Frank Lynwood	Chairman, U. S. Manganese Commission	Philadelphia
Halberstadt, Baird	Federal Fuel Administrator for Schuylkill Co., Penna.	Pottsville
Hoskins, Wm.	Consulting Chemist, Advisory Committee, Bureau of Mines; Associate Member, Naval Consulting Board	Chicago

Name	Appointment	Location
Hyde, Edward P.	National Research Council, Sub-Committee on Monocular vs. Binocular Field-Glasses (Chairman).	Cleveland
Insull, Samuel	Chairman, Illinois State Council of Defense	Chicago
Kennelly, A. E.	Conducting special course in radio-engineering for the U. S. Signal Corps, in conjunction with Prof. E. C. Chaffee	Harvard Univ.
Lloyd, E. W.	Asst. Secretary, Illinois State Council of Defense	Chicago
Lucke, C. E.	Civilian Director, U. S. Navy Gas Engine School	Columbia Univ.
Merrick, J. Hartley	Director, Bureau of Camp Service, Penna. Div., American Red Cross	Philadelphia
Milne, David	Treasurer, American Red Cross General Hospital No. 1	Philadelphia
Morris, Effingham B.	Treasurer, Committee of Public Safety, State of Pennsylvania	Philadelphia
Nichols, Carroll, B.	Fuel Administration	Washington
Nichols, Wm. H.	Committee on Chemicals, Advisory Council of National Defense, Consulting Chemist, Bureau of Mines	New York
Penrose, R. A. F., Jr.	Member of Geology Committee of the National Research Council	Philadelphia
Rapp, Isaiah M.	Special Investigator of Weights and Measures for the U. S. Food Administration	Norman, Oklahoma
Rautenstrauch, Walter	Committee of the National Research Council	New York
Richards, Joseph W.	Member of Naval Consulting Board	So. Bethlehem, Penna.
Robins, Thomas	Member and Secretary of the Naval Consulting Board	New York
Sperry, Elmer A.	Member of Naval Consulting Board	Brooklyn, N.Y.
Sprague, Frank J.	Member of Naval Consulting Board, Chairman, Committee on Electricity and Shipbuilding	
Stern, Max J.	Supervising Surgeon, Merchant Shipbuilding Corporation	Philadelphia
Stradling, George F.	Recruiting for Aviation Section, S.O.R.C.	Philadelphia
Swenson Magnus	Federal Food Administrator for Wisconsin; Chairman, State Council for Defense	Madison, Wis.
Talbot, Henry P.	Member of Advisory Board, Bureau of Mines (Gas Defense)	Cambridge, Mass.
Thomson, Elihu	National Research Council in coöperation with Council of National Defense	Swampscott, Mass.

Please send additional information and corrections to the Secretary.

RADIO SCHOOL OF THE FRANKLIN INSTITUTE

IN COÖPERATION WITH THE FEDERAL BOARD FOR VOCATIONAL EDUCATION.

Fifty-four of the students completed the required course, passed the necessary tests, and were inducted into the service of the army on April first

COMMITTEE ON SCIENCE AND THE ARTS.

(Abstract of Proceedings of the Stated Meeting held Wednesday, April 3, 1918.)

HALL OF THE FRANKLIN INSTITUTE,
PHILADELPHIA, April 3, 1918.

DR. H. JERMAIN CREIGHTON *in the Chair.*

The following report was presented for first reading:

No. 2708.—The Waterbury Hydraulic Speed Gear.

The following report was presented for final action:

No. 2709.—The Fahy Permeameter. Frank P. Fahy, of New York City, N. Y., recommended to the City of Philadelphia for the John Scott Legacy Medal and Premium.

On the recommendation of the Sub-Committee on Literature, the following awards were made for papers in the JOURNAL, 1917:

No. 2718.—The Howard N. Potts Medal to Dr. Alexander Gray, of Ithaca, N. Y., for his paper, entitled "Modern Dynamo Electric Machinery," described by the Sub-Committee as an exhaustive discussion of the design of dynamo electric machinery, with the details, both theoretical and practical, of successful commercial designs and their progressive development in the past decade; of especial value as a reference work for the designer of modern direct-current and alternating-current dynamo electric machinery.

No. 2719.—The Edward Longstreth Medal of Merit to Prof. Henry J. M. Creighton, of Swarthmore, Pa., for his paper, entitled "The Deteriorating Action of Salt and Brine on Reinforced Concrete," described by the Sub-Committee as presenting the results of an original and scientific investigation in a matter of great practical importance.

No. 2720.—The Edward Longstreth Medal of Merit to Dr. J. B. Whitehead, of Baltimore, Md., for his paper, entitled "The Electric Strength of Air and Methods of Measuring High Voltage," described by the Sub-Committee as a clear exposition of the underlying principles of the phenomenon of the electric corona at high potentials, a *résumé* of the present methods of high-tension electrical measurement, and a full description of a new and noteworthy instrument—the Corona Voltmeter, invented by the writer—and its application to important problems in modern electrical engineering.

GEORGE A. HOADLEY,
Acting Secretary.

SECTIONS.

Section of Physics and Chemistry.—A meeting of the Section was held in the Hall of the Institute on Thursday evening, March 7, 1918, at 8 o'clock, with Dr. H. J. Creighton in the chair. The minutes of the previous meeting were read and approved.

Dr. G. A. Hoadley announced the program of the meetings of the Philadelphia Section, American Institute of Electrical Engineers, for the remainder of the academic year.

W. D. Bigelow, Ph.D., Chief Chemist, Research Laboratories, National Canners' Association, delivered an address on "Scientific Research in the Canning Industry." The characteristic features of commercial and domestic canning were outlined, and various problems in the canning industry were described, with their solution. The paper was discussed by Doctors Hoadley, Hawk, Bigelow, and others. A vote of thanks was extended to Doctor Bigelow, and the meeting adjourned.

JOSEPH S. HEPBURN,
Secretary.

Mechanical and Engineering Section.—A meeting of the Section was held in the Hall of the Institute on Thursday evening, March 14, 1918, at 8 o'clock, with Dr. George A. Hoadley, acting secretary of the Institute, in the chair.

Doctor Hoadley announced that, owing to the demands that government work made upon the scheduled speaker of the evening, Major Louis A. Fischer, he had found it impossible to prepare his paper on "The Importance of Gauging in the Manufacture of Munitions."

Doctor Hoadley then introduced Mr. F. H. Shelton as the speaker of the evening, who delivered a lecture on "Windmills, Picturesque and Historic, the Motors of the Past." The speaker described the various types of windmills as developed in the different countries and the growth of these types with time. The relation of the Newport (R. I.) arch tower ruin to its prototype, an English windmill, was brought out in a very interesting manner and the character and history of this ruin thus fixed. The lecture was illustrated by a large number of colored lantern slides from original photographs and old engravings.

After a brief discussion the thanks of the meeting were extended to Mr. Shelton.

Adjourned.

LIONEL F. LEVY,
Secretary.

Section of Physics and Chemistry.—A meeting of the Section was held in the Hall of the Institute on Thursday evening, March 28, 1918, at 8 o'clock, with Dr. Harry F. Keller in the chair. The minutes of the previous meeting were approved as read.

George W. Littlehales, C.E., Hydrographic Engineer, U. S. Hydrographic Office, and Professor of Nautical Science, the George Washington University, Washington, D. C., delivered a lecture on "Oceanography." The history of the science of oceanography was outlined, and the methods and instruments of deep-sea research were described. An account was given of the depth and bulk of the ocean, the salinity, gases, temperature, pressure, compressibility, and viscosity of its waters, vision and penetration of light in its depths, distribution of atmospheric pressure on the ocean, winds on its surface, oceanic movements and circulation, life in the ocean, and marine deposits on its bottom. The lecture was illustrated with lantern slides.

A vote of thanks was extended to Professor Littlehales, and the meeting adjourned.

JOSEPH S. HEPBURN,
Secretary.

Section of Physics and Chemistry.—A meeting of the Section was held in the Hall of the Institute on Thursday evening, April 4, 1918, at 8 o'clock, with Dr. Gellert Alleman in the chair. The minutes of the previous meeting were read and approved.

Charles L. Reese, Ph.D., Chemical Director of E. I. du Pont de Nemours and Company, Wilmington, Del., delivered a lecture on "Explosives." A description was given of the ingredients, manufacture, and properties of black powder, brown powder, nitroglycerin, gun-cotton, explosive gelatine, explosive aromatic nitro compounds, other high explosives, and "permissible" explosives. The relationship between the explosives industry and the dye business was outlined. Laboratory and practical tests of explosives were shown by means of lantern slides, as were the uses of explosives in agriculture and engineering. The lecture was illustrated with specimens of raw materials, intermediate products, and finished explosives.

At the conclusion of the lecture the meeting adjourned.

JOSEPH S. HEPBURN,
Secretary.

Mining and Metallurgical Section.—A meeting of the Section was held in the Hall of the Institute on Thursday evening, April 11, 1918, at 8 o'clock, with Dr. Gellert Alleman in the chair. The minutes of the previous meeting were approved as read.

Arthur F. Taggart, E.M., Assistant Professor of Mining Engineering in the Sheffield Scientific School of Yale University, New Haven, Conn., delivered a lecture, entitled "An Explanation of the Flotation Process." A detailed account was given of the physico-chemical principles involved in froth flotation, their application in the concentration of sulphide ores of lead, zinc, and copper by flotation, the apparatus used, and the mode of operation. The lecture was illustrated with experiments and lantern slides.

The paper was discussed by Doctor Sadtler, Professors Dubois and Taggart, Drs. Carl Hering, Alleman, and Hepburn, and others. On motion of Dr. Walton Clark, seconded by Doctor Hering, a vote of thanks was extended to Professor Taggart, and the meeting then adjourned.

JOSEPH S. HEPBURN,
Acting Secretary.

MEMBERSHIP NOTES.

ELECTIONS TO MEMBERSHIP.

(Stated Meeting, Board of Managers, April 10, 1918.)

RESIDENT.

MR. WILLIAM HENRY BRADSHAW, Chemist, 1241 Carpenter Street, Philadeldelphia, Pa.

NON-RESIDENT.

MR. PERCY WEDLAKE, Metallographist, Washington Steel and Ordnance Company, and for mail, 707 Portland Street, Congress Heights, D. C.

CHANGES OF ADDRESS.

MR. WILLIAM E. ALLEN, 109 South Forty-third Street, Philadelphia, Pa.
MR. FRANCIS H. GILPIN, 400 South Fifteenth Street, Philadelphia, Pa.
LIEUT. HAROLD GOODWIN, 3927 Locust Street, Philadelphia, Pa.
MR. L. J. R. HOLST, 6035 Carpenter Street, Philadelphia, Pa.
MR. CARY T. HUTCHINSON, 65 West Fifty-fourth Street, New York City, N. Y.
DR. ENOCH KARRER, 45th Engineers, Company A, Camp Meade, Md.
MR. JAMES MILLIKEN, 734 Fifteenth Street, N. W., Washington, D. C.
MR. WALTER PALMER, 105 West Twenty-third Street, Chester, Pa.
MR. ALEXANDER E. REOCH, Marconi Wireless Telegraph Company, Aldine, N. J.
MR. ALBERT L. WEBSTER, 112 East Fortieth Street, New York City, N. Y.

NECROLOGY.

Mr. Caleb Cresson, 1706 Pine Street, Philadelphia, Pa.
Mr. Rowland G. Hazard, Peacedale, R. I.

LIBRARY NOTES.

PURCHASES.

CROFT, TERRELL.—Electrical Machinery: Principles, Operation and Management. 1917.
EFFRONT, JEAN.—Biochemical Catalysts in Life and Industry. 1917.
EKBLAW, K. J. J.—Farm Concrete. 1917.
EMMONS, W. H.—Principles of Economic Geology. 1918.
Industrial Arts Index.—Annual Cumulation, vol. 5. 1917.
International Catalogue of Scientific Literature.—A—Mathematics, vol. 14. 1914.
JANSKY, C. M.—Theory and Operation of Direct-Current Machinery. 1917.
Reader's Guide to Periodical Literature, vol. 17. 1917.
Reader's Guide to Periodical Literature, Supplement, vol. 5. 1917.
ROBERTSON, T. B.—Physical Chemistry of the Proteins. 1918.

STERLING, F. W.—Internal-combustion Engine Manual. 1917.

STOKES, RALPH, and Others.—Text-book of Rand Metallurgical Practice, 2 vols. 1911.

TRAVERS, GUPTA, and HAY.—Some Compounds of Boron, Oxygen, and Hydrogen. 1916.

WAGNER, F. H.—Coal Gas Residuals. 1918.

WAGNER, J. B.—Seasoning of Wood. 1917.

GIFTS.

Allis-Chalmers Manufacturing Company, Bulletins of Agricultural Machinery; Air Brakes; Electrical Machinery; Flour Mill Machinery; Mining Machinery; Crushing and Cement Making Machinery; Prime Movers, Air Compressors, Hoists and Fans; Pumping Machinery and Hydraulic Turbines; and Saw Mill Machinery. Milwaukee, Wis., 1905–17. (From the Company.)

American Institute of Electrical Engineers, Year-Book, 1918. New York, 1918. (From the Institute.)

American Institute of Mining Engineers, Officers, Members, Rules, etc., March 1, 1918. New York, 1918. (From the Institute.)

American Railway Tool Foremen's Association, Year Book, 1917. Chicago, 1917. (From the Association.)

American Society of Civil Engineers, Transactions, vol. lxxxi, December, 1917. New York, 1917. (From the Society.)

American Telephone and Telegraph Company, Annual Report of the Directors for the Year Ending December 31, 1917. New York, 1918. (From the Company.)

Ashton Valve Company, Catalogue No. 12A. Boston, Mass., 1914. (From the Schade Valve Manufacturing Company, Philadelphia.)

Bird-Archer Company, A Practical Treatise upon Marine Boiler Deterioration; The Bird-Archer Treatments for Boilers; and Polarized Metallic Boiler Chemicals. New York, 1907, 1914, 1915. (From the Company.)

Broderick and Bascom Rope Company, Aerial Wire Rope Tramways. St. Louis, Mo., no date. (From the Company.)

Bryant Chucking Grinder Company, Bryant Production Book. Springfield, Vt., 1918. (From the Company.)

Buffalo, Rochester and Pittsburgh Railway Company, Thirty-third Annual Report for the Year Ending December 31, 1918. New York, 1918. (From the Company.)

Canada Department of Mines, Mines Branch, Preliminary Report on the Mineral Production of Canada During the Calendar Year 1917. Ottawa, 1918. (From the Department.)

Canadian Pacific Railway Company, Annual Report for the Fiscal Year Ended December 31, 1917. Montreal, 1918. (From the Company.)

Carlyle Johnson Machine Company, The Johnson Friction Clutch as Applied in Machine Building. Manchester, Conn., 1912. (From the Company.)

Carnegie Institution of Washington, Year Book No. 16, 1917. Washington, 1918. (From the Institution.)

Channon, H. Company, Catalogue No. 80, Machinery Tools, and Supplies. Chicago, 1916. (From the Company.)

Cleveland Automatic Machine Company, Thirty-one Articles by J. P. Brophy. Cleveland, Ohio, no date. (From the Company.)

Coburn Trolley Track Manufacturing Company, Catalogues Nos. G-3, 47, 48, 50, and 51. Holyoke, Mass., no dates. (From the Company.)

Colorado Iron Works Company, Catalogue No. 28-C, Continuous Filtration with the Portland Filter. Denver, Col., 1918. (From the Company.)

Cornell University, The Register, 1917–18. Ithaca, N. Y., 1918. (From the University.)

Cumulative Digest Corporation, Business Digest, July-September, 1917. New York, 1917. (From the Corporation.)

De la Vergne Machine Company, Ammonia Fittings Catalogue. New York, no date. (From the Company.)

Delaware College, Annual Catalogue, 1917–18. Newark, 1918. (From the College.)

Direct Separator Company, Steam and Oil Separators. Syracuse, N. Y., 1916. (From the Schade Valve Manufacturing Company, Philadelphia.)

Doak Gas Engine Company, Bulletins Nos. 12, 14, 31, and 51, of Doak Engines. Oakland, Calif. 1914–18. (From the Company.)

Florida State Geological Survey, First, Sixth, and Eighth Annual Reports, 1907–15. Tallahassee, 1908–16. (From the Survey.)

Gilbert and Barker Manufacturing Company, The Gilbert & Barker Process for Burning Fuel Oil Under Low Pressure. Springfield, Mass., 1918. (From the Company.)

Great Britain Meteorological Office, British Meteorological and Magnetic Year Book, 1914, part iv. London, 1917. (From the Office.)

Greenfield Tap and Die Corporation, Gun Tap Booklet. Greenfield, Mass., 1917. (From the Corporation.)

Hamilton Library Association, Report of the President for the Year 1917. Carlisle, Pa., 1918. (From the Association.)

Harrison Safety Boiler Works. Finding and Stopping Waste in Modern Boiler Rooms, vols. i and ii. Philadelphia, 1917–18. (From the Company.)

Hilles & Jones Company, Catalogue No. 8, of Machine Tools. Wilmington, Del., 1916. (From the Company.)

Hobart College, Catalogue, 1917–18. Geneva, N. Y., 1918. (From the College.)

Hoover Steel Ball Company, The Evolution of the Steel Ball Industry. Ann Arbor, Mich., no date. (From the Company.)

Hydro-Electric Power Commission of Ontario, Ninth Annual Report for the Year Ended October 31, 1916, vols. i, ii, and iii. Toronto, 1917. (From the Commission.)

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In view of the abundance of French literature of all types at present in this country, there would seem to be but a limited field for this book. Only favorable criticism can be made of it, for it contains a large amount of interesting information. After some preliminary matters, relating to the grammatical structure of the French language, essays on many important topics in chemistry are given, and about one hundred and sixty pages of reprints of important articles, originally appearing in that language. Among these are articles by Berthelot, Grignard, Pasteur, and Curie. A useful table of the accidence of the principal irregular verbs, and a small vocabulary close the volume. There is no index, but this is hardly needed in such a book.

HENRY LEFFMANN.

STEAM BOILERS: A PRACTICAL AND AUTHORITATIVE DISCUSSION OF BOILER DESIGN AND CONSTRUCTION, AND THE DEVELOPMENT OF MODERN TYPES. Revised by Robert H. Kuss, M.E. Chicago, American Technical Society, 1917. 82 pages, 74 illustrations, 8vo., cloth. Price, $1.

There is a demand among many engineers and designers for reference works describing approved practice in the simplest possible terms and devoid of difficult analytical discussions. Among books appearing in recent years that meet this requirement, though written for a different class of users, are the beautifully illustrated and well-executed texts issued by some of our correspondence schools. The present volume is of this type. About fifty pages are devoted to the elements of design, with illustrations of typical details. The remainder of the work is essentially an album of standard types of boilers in common use, with brief descriptions and notes. It is a compact, typographically well-executed book which will appeal to those who desire condensed information on the structural features of commonly used types of boilers.

LUCIEN E. PICOLET.

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The Physical Chemistry of the Proteins, by T. Brailsford Robertson, Ph.D., D.Sc. 483 pages, 8vo. New York, Longmans, Green & Co., 1918. Price, $5.

Mechanical Laboratory Methods: The Testing of Instruments and Machines in the Mechanical Engineering Laboratory and in Practice, by Julian C. Smallwood, M.E. Second edition, revised and enlarged. 399 pages, illustrations, 12mo. New York, D. Van Nostrand Company, 1918. Price, $3.

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CAMP SANITATION.*

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In these days of military activity, with soldiers widely scattered throughout the land, a camp is naturally conceived of as having to do with war, and relatively little thought is given to those gatherings of men who are occupied with the activities of peace.

Certain well-defined differences must be recognized between labor camps and those of soldiers, the most notable of which is the existence of military authority in the one and its entire absence in the other. When provision is being made for a group of men accustomed to obey orders, who are equipped in all particulars with uniformity, who are subject to military authority, and who are protected thereby from the dangers of irregular and vicious living, the camp problem assumes a simplicity of solution quite in contrast with that presented when arrangements have to be made for a collection of persons gathered from many sources, frequently of many nationalities and different languages, often very ignorant, and all imbued with a spirit of independence that causes them to resent what they believe to be an interference with their personal liberty.

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In perhaps no other way is their resentment so likely to be aroused as by attempts to control their movements during off-hours. Any approach toward making prisoners of camp employees is bound to produce resistance on the part of a majority of them, even though the more intelligent few may be persuaded of the advantage accruing from stopping a too free passage to and from the general enclosure. A man-proof fence with single gateway has its advantages, even though no physical interference be attempted with an inmate passing the guard.

Camps are sources of potential damage not only to their own people but also to the inhabitants of the district wherein they are located, particularly to those who dwell down stream in the same valley. Pollution of a public water supply, either direct or through injury to its general water-shed, may become serious unless guarded against by competent sanitary supervision.

This supervision may be undertaken by those in responsible charge of the camp or else by the sanitary authorities of the municipality threatened. It would be better if it were carefully looked after by both, although it often fails to receive the attention of either.

There is abundance of law upon the statute books wherefrom the local health officer can draw all the power needed to meet the situation, but it too frequently happens that the power is not evoked until the threatening menace has developed into an actual disaster. The public itself should not be required to look into matters of health protection, for the sufficient reasons that they do not possess the skill and have, moreover, delegated a presumed expert to do that sort of work for them; consequently many sanitary sins will be overlooked, particularly if rectification should call for heavy demand upon the treasury.

When something serious does happen, however, the public energy will act with great vigor to abate an existing and manifest evil, even though the ounce of prevention that could have saved the day was at an earlier period considered an unnecessary expense.

Of all the forms of danger which may accompany camp life, that arising from the presence of human dejecta is the one requiring the most serious consideration. How shall this material be handled so as to deprive it of power to become a menace to health?

Even when the number of men employed upon a job is small, it will never be wise to allow them free license to act as they see fit in the matter of disposing of their bowel discharges. This is particularly true if the job be one involving the possible pollution of a public water supply.

So simple a device as a "straddle trench" is quickly made and easily cared for and, if well located, possesses the advantage of placing the material collected in a portion of the soil where pathogenic bacteria will find conditions least likely to favor their longevity.

As illustrating the great difference in numbers of ordinary bacteria found at sundry depths, the following counts are given per gramme of dry meadow soil:

Immediately under the sod	114,000
1 foot below	47,800
2 feet below	39,000
3 feet below	9,500
4 feet below	6,700

A straddle trench should be dug twelve inches wide, twelve inches deep, and as long as circumstances demand. Dejecta placed therein and covered at once with the excavated earth will be quickly destroyed, in contrast with what happens to it when deposited in pits many feet deep. In the latter case the action is one of imprisonment rather than destruction.

Anyone who has had occasion to uncover very old and large privy pits will recall the exceedingly foul condition in which the contents were found, even after the lapse of many years, while, on the other hand, the appearance of the soil turned by the plough in any field which has been repeatedly manured will furnish illustration of how quickly animal droppings will disappear after shallow burial.

It would seem scarcely necessary to urge attention to the selection of a proper site for a straddle trench, and yet it was lack of good judgment in such a matter that caused an outbreak of typhoid fever in a New England community through the washing out by heavy rainfall of dejecta carelessly buried on a steep hillside.

It takes but little infected material to produce great damage if the point of its introduction be a vital one. This was instanced at Plymouth, Pa., when the dejecta of a single typhoid patient caused the illness of over twelve hundred people. Nevertheless, it is manifestly wiser to take chances on a little rather than on much of a dangerous article, particularly if that little be so distributed as to encounter conditions favorable to its destruction.

If the dejecta in the Plymouth case, instead of being accumulated upon a steep and rocky hillside during a northern winter, had been scattered upon a flat and sandy southern soil, the polluting material would have been easily and safely disposed of and no disaster would have occurred.

No more safe method of disposal for small amounts of night soil can be secured than placing it in small lots just under the surface of the ground in a level sandy loam. It is the privy system at its best.

How the ancient Hebrews looked upon this matter may be judged from the following: "Thou shalt have a place also without the camp, whither thou shalt go forth abroad: And thou shalt have a paddle upon thy weapon; and it shall be, when thou wilt ease thyself abroad, thou shalt dig therewith, and shalt turn back and cover that which cometh from thee." Deut. 23: 13.

Perhaps it may be not generally known that a device has been under trial by one or more railroads whereby a certain speed has to be attained by the car before the toilet pans can be dumped. While the train is standing at stations or while it is slowly approaching or leaving them the pans are automatically locked. The advantage, so far as cleanliness of the stations is concerned, is apparent, but benefit reaches further than that, for the reason that the material discharged at a high rate of train speed is spread over much ground, which increases the opportunity for natural purifying agencies to do their work.

A simple, old-fashioned privy system is often the only one which will fit camp conditions, but deep pits are then usually a necessity. Flies must be absolutely excluded from the possibility of reaching the excreta, seat covers must always be provided and must be so constructed as to be self-closing when the seat is vacated, and the ventilating window must be screened. The seat box should be movable to allow of the pit being burned out with straw and oil three times a week, if not oftener.

As camps grow in size the labor of properly caring for them increases. Men have to be employed whose entire time is devoted to sanitary work. Proper water carriage of sewage, night-soil removal, and incineration of garbage are matters that fall under the care of such men.

A complete water-closet system contemplates sewers and also a disposal plant, unless there be available either some large body of water into which raw sewage can safely be discharged, or else an almost unlimited area of suitable sandy soil for disposal by irrigation. At one of our cantonments where some thousands of men are collected the raw sewage, after coarse screening, is run into a blind ditch in the sand, which ditch is simply extended as its side slopes and bottom becomes clogged. Clogging is delayed by suitable use of a rake. Nothing could be simpler, but the character of the soil requisite for such a solution of the sewage problem is rarely found, and when found cannot be unduly overworked.

The most novel proposition, involving a serious overload, that the writer ever encountered had to do with sewage disposal in a town in the Far West where deep wells were available which delivered much water under heavy pressure. The proposition was to use this artesian water to shoot the sewage into the air and thereby so distribute it over the country as to render it unobjectionable. One can imagine the state of things that would have resulted had such an odd plan been adopted.

A sewage disposal lay-out of a municipal type cannot be considered for a camp except under circumstances of decided permanency and when provision is to be made for a large body of men. At a number of our present military establishments we possess such systems of treatment, but labor camps are nearly always in quite another class.

Night-soil removal, or the can system, involves burying the can contents or else burning them, and the decision is sometimes in favor of employing both methods, although burying is the more common. There is an often-expressed objection to the burning of this sort of material because of a fancied unpleasant smell resulting, and yet it is really hard to detect any real difference between the odor so produced and that evolved by the combustion of almost any kind of organic material. Major Lelean quotes an interesting letter from a lady who wrote as follows: " The odor of burning peat, so delightfully reminiscent of the cotter's hearth, becomes the intolerable effluvium of burning matter of an indescribably objectionable nature " when excreta are being burned. Inasmuch as the letter of objection was received when a wood fire was employed to try out the furnace, and before any excreta had been added, the Major was induced to seriously discount subsequent objections.

Many types of incinerators are in use, some of which are decidedly complex and expensive.

For a simple device, calculated to provide for a reasonable number of men, and especially suitable for garbage destruction, the Woodruff pit is worthy of attention. It is merely a circular hole in the ground, ten feet in diameter and about four feet deep, with the sides lined up with field stones. In the centre is a conical pile of the same stones to act as a sort of draft chimney. This pile can be advantageously supplemented by a couple of lengths of tile pipe or even old stove pipe. A good fire of wood having been started in this pit, a very considerable amount of camp refuse can be disposed of by judicious firing. Liquids should be slowly poured down the hot side stones so as to encourage rapid evaporation. If liquids be added in too great a bulk or thrown on too quickly they are likely to pass the fire zone and reach a lower level where they may start a nuisance.

One disadvantage of the Woodruff pit or of any other type of open fire is that when the wind is high light materials will often be blown about the camp; this is especially objectionable if the said materials chance to be what are known as " camp butterflies " or toilet paper.

Urine can be well disposed of by the stone-filled soakage pits, adopted by the British Army, into which long funnels of wood or tin are extended. Fouling of the ground with consequent fly infection is thus avoided.

At one large New York camp a non-portable furnace was built which worked successfully. It consisted of three levels, of which the bottom one held the fire. The top level was a shelf extending from the front half-way or more toward the back wall, and upon this shelf was thrown the material to be destroyed. The middle level was also a shelf of about the size of the top one, but it extended from the back wall out toward the front. Thus the hot products of combustion followed a curved course under and over the materials on the two shelves. When the charge on the top shelf had become thoroughly dried it was pushed back so as to fall on the middle shelf, and when it had thoroughly charred in that position it was pulled forward and fell upon the fire.

A military furnace may be seen at Plattsburg which is operated without drying shelves. Its length is greater than its height, and the garbage charge is dumped directly upon the fire through a trap-door. The fuel is cord wood. Around the sides of the combustion chamber run iron water pipes that act like the waterback of a kitchen range and supply hot water with which to wash the cans in which the garbage is collected. The process is not continuous, and a new fire has to be started every morning.

While garbage is usually incinerated in a furnace such as this or in a Woodruff pit or in some still simpler arrangement burning either wood or coal, yet it generally contains so much combustible material that a device less costly in the matter of fuel consumption is to be preferred.

The Canadian camps, or at least some of them, are using a furnace, called the Reid incinerator, which is designed to operate continuously without any other fuel than that contained in the garbage itself after an initial fire of wood has been built as a starter.

In this type of apparatus a supporting grate-like set of bars is provided which suspends the garbage load and counteracts tendency to clogging. A further peculiarity of construction is a number of drawer-shaped draft holes which may be opened or closed at will, and which admit air to sundry well-spaced points throughout the body of the garbage charge.

The successful running of the Reid incinerator demands that enough garbage be supplied to keep the apparatus working on approximately full capacity.

Colonel Nasmith, of Toronto, advises the writer that while at the front in France excellent results were secured by constructing incerator walls out of old oil cans filled with puddled clay. After a wall built in such a manner had been fired it proved very stable. Similar cans used empty produced a reliable chimney and old railroad iron thrust irregularly through the furnace walls supplied supports for the garbage charge and permitted air to reach scattered points throughout the mass.

Doctor Nasmith found advantage to follow the introduction of old tin cans of every description into the furnace with the garbage, as thereby a desirable "porosity" was given to the material being burned.

Horse manure can be burned by arrangement such as just described, but the destruction of valuable fertilizing material savors of decided waste, and, moreover, a labor camp rarely contains enough horses to demand military measures.

Fifty horses will make about a wagonload of manure daily, but, however small the volume may be, provision must be made to prevent its becoming a breeding place for flies. Usually, although not always, farmers are found willing to cart manure away for use upon their crops, in which case it is of interest to be certain that it is hauled to a sufficient distance before it is piled; otherwise, as a large camp presents many attractions for flies, the insects are likely to find it if the haul should be a short one. Major J. M. Phalan, U. S. A., believes that the only safe haul is one by railroad, for the reason that a distance likely to be covered by ordinary wagon hauling would probably prove much too short to prevent the flies reaching camp.

However much the average farmer may value good manure which is given to him, the labor camp is frequently so placed as to make the use of its horse droppings for fertilizer unprofitable because of the expense of removal. A small amount of manure can be made "fly-proof" by a liberal wetting down with solution of copperas, but a much better treatment is that of destruction by fire. Windrows less than two feet high can be successfully burned if sprinkled with crude oil.

Before leaving the question of flies we should remember that a single insect can produce nearly a million descendants during a season. They feed to a large measure upon fæces, and their bodies and legs are covered with hairs, so that they can act as distributers of pathogenic organisms by vomiting upon human food, by defecating over it, and by wiping their filthy feet upon it.

So much has been written upon the necessity of protection against flies and mosquitoes that it is simply needed here to insert a reminder that the development period, from egg to mature form, of each of these insects is practically the same; namely, about two weeks. Precautions in the way of thorough screening of quarters, removal or destruction of horse manure, and oiling or draining of water pools, however small, must be faithfully practised throughout the breeding season.

Only a word can properly be said here upon the general subject of "housing," because upon that topic there are far too many variables to allow of a fair standardization of labor camps. Five hundred cubic feet of air space per man should be supplied in the sleeping quarters, and mosquitoes should be excluded by careful screening.

Each camp must be treated upon a plan of its own and local conditions must govern. The construction of proper ditches to receive roof drip and the use of the material excavated from these for "banking" the outer walls against drafts along the floor naturally suggest themselves as suitable procedures.

Sleeping accommodations of the "bunk" form are more compact and are cheaper than cots placed side by side. They have the disadvantage of being more difficult to keep clean than the open arrangement, but, on the other hand, communicable diseases are not so easily transmitted under crowded conditions.

Both one-story and two-story barracks have their advocates. The two-storied forms are certainly cheaper to heat per capita, and they are also less expensive in the matter of cost of roof construction, calculating upon the same basis.

The following description by Meriwether of prison barracks may be inserted here:

"They occupy what are called Adrian barracks, which are built of wood, in sections one hundred feet long by twenty-five feet wide. The necessary parts are standardized and can be quickly assembled. After each big battle a quantity of the parts is rushed to the desired point, and within a few hours accommodations are ready for the captured men. On the day of our visit the camp contained eleven hundred and ninety-eight prisoners, but three hundred and sixty more were to arrive the next day, and quarters for the newcomers were being assembled.

"Each barrack contains two rows of two-story bunks, the upper bunk being placed four feet above the lower. In the centre between the two rows of bunks is an aisle provided with long tables and benches. Electric lamps light this centre aisle, and the prisoners use the tables as dining-tables and for playing games and writing letters.

"In another the grounds of the camp were drained by subsoil pipes. The wooden barracks, heated by stoves and lighted by electricity, contained bunks raised eighteen inches above the wood floors. Each bunk was provided with a straw mattress and two woollen blankets."

Camps being but temporary in character, a due consideration of the "economic period" for which they are built naturally controls to a large degree the design of the quarters.

In localities of special danger, as when new construction or repairs are in progress in the immediate vicinity of some public water supply, the care exercised in the camp itself must be extended to the site of the work as well. The thoughtlessness that a labor gang can exhibit upon occasion is simply amazing.

It would seem sufficiently careless to deposit fecal matter upon the steep bank of a stream a short distance above a city intake, but the writer has seen the same material dropped in the open end of a cast-iron water main as it lay in the ditch. Nothing but careful sanitary supervision can meet such abuse.

Naturally the officer in charge of formulating the rules governing the camp, if worthy of his responsibility, would see to it that the regulations were suited to the local conditions and, while strict enough to safeguard health, were not so loaded with unnecessary caution as to become a burden. No hard-and-fast rule can be laid down which will state, for instance, the exact point beyond which pollution will become dangerous and short of which one can count upon safety. The writer had upon one occasion testified that five thousand head of cattle would seriously damage the water of a certain stream upon the banks of which they were corralled. The cross-examiner asked if twenty-five hundred would likewise cause serious pollution, and the answer was "Yes." The next question was, "Would twelve hundred cattle produce serious pollution?" To this the reply had to be made that "while willing to halve the number of cattle actually covered by the facts in the case at issue, it would be unwise to attempt further division, for fear of finding a single cow polluting the entire valley."

The prominence usually given to what may be termed the auto-intoxication of a camp may well mask the equally important matter of the danger a camp may be to the well-being of those whose homes are in the same drainage area. Camps are, of course, of all sizes, depending upon the magnitude of the job, but it is no error to assume that for the same quantity of proposed work a larger number of laborers must now be provided than were needed for the same work a few years ago. As an instance, it was formerly common on railroad construction to find four men carrying a hundred-pound rail, where now twelve are demanded; and, while one man could in the past shoulder a railroad tie, it now must be lifted by two men, one at each end, except in those cases where the tie is creosoted, when four men using lifting tongs are required.

Of course, such circumstances increase not only the expense of construction but they also call for greater vigilance to provide against sanitary risks arising from enlarged camp population.

Nothing short of conscientious sanitary inspection, followed by promptness in necessary action, can meet the difficulties that confront those in charge of water-shed protection.

It is of the utmost importance that engineers and foremen should remember that in a very real sense they are health officers and sanitary instructors as well. The men under their care are likely to be largely ignorant of elementary sanitation and need both instruction and advice. If the camp be sufficiently large to support a meeting hall, great good will follow the inauguration of lectures and instructional moving pictures. Not only needed information is thereby supplied, but entertainment also.

It goes without saying that the camp water supply is a matter of major importance, and it is the manifest duty of the parties in charge to so arrange matters that a suitable volume shall be always available and that its quality shall be suitable as well. Small groups of men can usually be safely supplied locally, but large camps may demand the exercise of considerable skill of a special character to meet their needs. No haphazard guessing nor the application of household tests should be employed to determine the suitability of a water for use in a large camp. At this point we are reminded of a quaint old book by John Smith, printed in 1712. Its title is "The Curiosities of Common Water, or the Advantages Thereof in Curing Cholera, Intemperance, and Other Maladies." In it we note: "How to distinguish water." "The way to do this is by the taste and scent—for if it have no taste nor smell, being purely fresh, nor salt, nor sweetish, nor ill-scented, it is good, provided it be pure and clear." "All water that will make good lather with soap is wholesome to drink without boiling, but none else."

It may be that no little difficulty will be encountered in persuading the men to avoid the attractive water from some polluted well and use the safer camp supply, as the latter may have been carried some distance in slightly buried pipes and consequently be lacking in coolness. If the camp water should have a taste due to algæ, there would be still greater difficulty in securing its use. Algal taste can be successfully removed by a small dose of potassium permanganate, as first proposed by Houston. Removal of the means of raising the water from an open and polluted well is the best plan for stopping its use if such a procedure be permissible. Deep or driven wells furnish supplies that may be nearly always accepted with confidence.

Bathing should be encouraged, and, unless the camp be very small, showers of simple construction should be built. In the absence of showers, abundant provision should be made for the washing of both body and clothes, and no charge should be made for soap.

To insist upon and secure periodical bathing is rather more than those in charge of labor camps can accomplish: all they can do is to see to it that provision is made for maintaining cleanliness and leave the rest to the discretion of the men. Fifty gallons of water per day per capita should be supplied to large camps; this will very liberally suffice for all purposes.

It is interesting to observe the economies that have to be practised during the present war in localities where water is scarce: thus we note in the *Journal of the Royal Army Medical Corps,* 27: 363: " Baths at the front where water is scarce. Add lime to the water after use and mix by hand power. Insoluble lime soap separates, settles, and carries down impurities. Settlement is effected in three successive concrete tanks. Sodium carbonate is added to the water in the third tank, whereby calcium carbonate is precipitated and oils are caused to float. The latter are absorbed by sacking on frames. After settling in this third tank, the water is passed through a charcoal bed four inches thick." The water treated as above is described as quite clear and " free from dirt, soap, lime, and soapy oils." The same water is used indefinitely.

As to the character of the pipe for camp plumbing and the possibility of its being acted upon by the water carried, there is not the same necessity for careful selection as when more permanent construction is being undertaken. "Red water," due to an attack upon iron by a soft surface supply, is not likely to appear immediately, so that even an inferior galvanized pipe will probably last long enough to outlive the purposes of the camp, and we know that action upon the protecting coating, whereby zinc is carried into solution, will cause no injury to those drinking the water. Large amounts of zinc have been swallowed by sundry communities over long periods of time without ill effects. Thus Hazen reports that at Brisbane, Queensland, the water, which is stored in tanks built of galvanized iron, contains over seventeen parts per million of zinc, yet no harmful effects have been observed after years of use. A number of city water supplies of Massachusetts have been reported by the State Board of Health as containing zinc, but no evil results due to its presence have been reported.

In the State of New York certain rules are formulated by the Commissioner of Health which work hardship to no one and which materially aid in conserving the health both of the camp and of the neighboring communities. Among the requirements, we observe that even for so small a labor camp as one holding ten people a permit must be secured if the camp site is to be occupied for over six days.

If there be twenty people in the camp, then a camp care-taker must be appointed.

No camp building of any kind shall be erected within fifty feet of a stream or lake furnishing public water supply.

Any privy located within from fifty to two hundred feet of said stream or lake shall be built without a vault and its dejecta shall be removed daily to a distance of at least two hundred feet from the water's edge before being buried or incinerated. A number of states have similar sanitary rules, but unfortunately others do not.

Engineers in charge of even large labor camps could scarcely be expected to have the camp cooks examined to determine if they were "typhoid carriers" or to provide "typhoid vaccination" for the men; neither could it be expected that they should look after the cleanliness of their employees to the extent of ridding them of body vermin, nor is it likely that the latter attention would be acceptable to the employees if it were offered.

A feeling of thankfulness should develop upon the thought that supervision does not have to extend so far, for the thorough accomplishment of that kind of an undertaking is a task indeed. One has but to note the almost endless detail and yet perfect smoothness of running in the matter of managing that disagreeable job among the troops now in France in order to appreciate how much the commander in civil life is spared. To quote from a prominent military authority: " It takes from 8 A.M. to 4.40 P.M. to attend to the thorough 'de-lousing' of 1400 men. This includes washing of the bodies and the washing, steaming, and drying of their clothes."

To conclude, we see that the proper management of a labor camp is largely founded upon common-sense and good judgment, with an additional allowance of that extra sense called " tact," which enables one to get along efficiently and smoothly with other men.

A New Standard of Current and Potential. C. F. Alcutt. (*Proceedings of the American Institute of Electrical Engineers,* vol. 37, No. 2, p. 83, February, 1918.)—The increasing use of potentiometers in commercial service, especially in connection with the measurements of temperature by means of thermocouples, makes it very desirable to secure a substitute for the standard cell usually required by these instruments. The serious shortage of standard cells caused by the war has emphasized this need. Furthermore, it is being recognized that it is poor economy to use a costly precision standard in a commercial potentiometer which reads to three significant figures at the most.

The new standard which is proposed as a substitute for the standard in certain classes of direct-current measurements is essentially a Wheatstone bridge which will balance for but one value of the current. The device consists of a Wheatstone bridge comprising three constant resistances, and a fourth element whose resistance is a function of the current flowing through it. In practice the resistance element consists of an evacuated glass bulb which encloses a fine filament of material having a relatively high temperature-coefficient of resistivity. The practicability of the device depends on securing a variable resistance having the desired current-resistance characteristics, together with a high degree of permanence. A bridge of this type was designed to balance with a current of 20 milliampères, and having just one volt potential difference when the bridge is balanced. The work done in connection with the development of this new standard has demonstrated that it may be relied upon to maintain an accuracy of plus or minus 0.1 per cent.

THE NON-MOLECULAR STRUCTURE OF SOLIDS.*

BY

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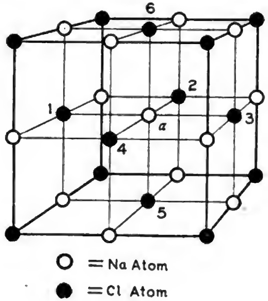
ONE of the most striking things in the structure of crystals as worked out by Prof. W. H. and Mr. W. L. Bragg † is the orderly manner in which the atoms of the different crystals are arranged. The evidence of X-ray analysis points definitely to a structure in the simple crystals which have been examined in which there is no evidence whatever of any grouping of the atoms into molecules. It seems rather that the position of an atom depends equally upon all the neighboring atoms, so that the whole

FIG. 1.



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* Communicated by the Author.

Contribution from the Research Laboratory of the Westinghouse Lamp Company, East Pittsburgh, Pa., January 5, 1918.

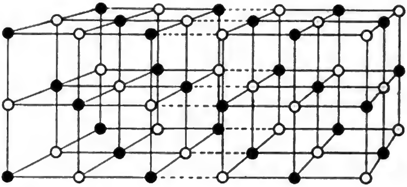
This paper was sent to three members of the Physics faculty at Princeton University on July 25, 1914. It was read before the Physics Colloquium of Princeton University on October 8 1914. Though not originally prepared for publication, the subject has become one of such general interest that it has been thought worth while to publish the article at this time without alteration.—THE WRITER.

† Proc. Roy. Soc., 1913–1914.

mass is a homogeneous bundle of atoms which have no tendency to form into molecules.

If we take, for example, a crystal of rock-salt, we find the atoms of sodium and chlorine arranged alternately in a simple cubic pattern (Fig. 1). Any one sodium atom *a* is equally strongly bound to any one of six chlorine atoms, 1, 2, 3, 4, 5, 6, or *vice versa.* It is evident that it is easy for the atoms to pair off into molecules on passing into the liquid state. In doing so, however, there are equal probabilities for an atom to combine with any one of six others, so that we cannot expect the same pair of atoms to form a molecule after the substance melts as were together before they assumed the solid state. Thus no particular pair of atoms in the crystal can be said to belong to the same molecule.

FIG. 2.



In order to make more evident the absence of true molecular structure, let us consider a salt crystal to be made up of two cubes (Fig. 2), each cube having an odd number of atoms on its edge. Then the whole crystal has an equal number of sodium and chlorine atoms, but if it be split in the middle, one half will contain an excess of chlorine and the other of sodium atoms. Thus by the simple operation of splitting the crystal along a cleavage plane we must have performed the exceedingly delicate operation of mechanically severing a molecule into two parts—a chemical process—if there is a true molecular structure in the crystal. Exactly similar arguments show the non-molecular structure of the other kinds of crystals which the Braggs have determined.[1]

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[1] So far as the writer is aware, the fact that the work of the Braggs thus indicates a non-molecular structure in the crystals which they examined was first pointed out by him in *The Scientific American Supplement,* July 4, 1914, page 5.

In these simple crystals, then, if the structure as determined by X-rays is correct, each atom is held in position equally by all the neighboring atoms. It is natural to suppose, therefore, that in substances which are chemically more complicated, as in these simple crystals, each atom is affected by forces equal, on the average on all sides, so that there will be no grouping into molecules. Thus by the definite indication by X-ray analysis of a non-molecular structure for certain simple crystals we are led to the idea that very possibly the structure of all compounds, however complicated, is non-molecular in the solid state.

We may therefore state the thesis that we hope to prove, thus: *Every atom in a solid has its position so determined by the other atoms that it cannot be said definitely to belong or not to belong to the same molecule as some other one atom.* That is, in the solid state the atoms of the substance are so intimately intermingled that particular molecules cannot be definitely defined. Since this proposition is apparently not in accord with the generally accepted molecular theory of solid matter, it is important to see how it is confirmed by a study of the general properties of matter as well as by the molecular theory itself. In this way we hope to form an argument which will show that *non-molecular structure is an essential attribute of all solid matter.*

ARGUMENT FROM THE PROPERTIES OF SOLID MATTER.

From an historical standpoint, the way in which the conception of molecules in the solid state was formed was by a deduction from the kinetic theory of gases. It was easy to explain the change from gas to liquid as due to a shrinking of molecular distances to something comparable with the diameter of the molecules, at which distance the molecules would be held together by intermolecular forces. Likewise the passage from the liquid to the solid state was explained as the settling of the molecules into positions of stable equilibrium. Since the molecules have a definite form in the gaseous state, it was natural to suppose that they would keep this form in the liquid and solid states. We have already seen, however, that there is no trouble with an explanation of the passage from the solid to the liquid state, even with a non-molecular structure in the solid. For example, NaCl, which is known to have a non-molecular structure, actually does melt, so that a molecular structure of the solid is not necessary. The explanation of this we saw was simply that the atoms in the salt crystal paired off when assuming the liquid state. Since, therefore, a non-molecular structure accords as well with the general kinetic theory of gases and liquids as does a molecular solid, there is no *a priori* reason why solids should be molecular in structure.

It will be convenient, however, to speak of the atoms in the solid state as belonging to molecules, meaning either the molecules to which they belonged before assuming the solid state or those to which they will belong if they assume again the liquid or the gaseous state.· We shall then employ a sort of *reductio ad absurdum* method, and try to show that these groups of atoms cannot exist in the solid as definitely defined molecules.

In order to prove the thesis as stated above, it will be necessary to show that at least some of the atoms of every molecule are bound as strongly to atoms of other molecules as they are to their own. It is evident that this means a non-molecular structure, since there can be no definable boundary to the molecules in such a case. We shall attempt to prove this point by steps, showing:

1. That each atom in a solid oscillates about a definite position of stable equilibrium.

2. That the forces holding the atoms in their positions of stable equilibrium are of the same nature and are comparable in magnitude with the forces binding together the atoms of the same " molecule "; and

3. That at each of the frequent collisions the forces between the atoms of different " molecules " become so great that an atom has even chances to be torn from the atoms of its own " molecule," so that, on the average, it is bound equally to all the neighboring atoms.

The evidence for the fact that each atom has a definite position in a solid is well known. In the first place it is a generally accepted part of the molecular theory that in the solid state the molecules are in positions of stable equilibrium from which they hardly move. The fact that a true solid will not change its shape under small forces even for great periods of time shows that the molecules are not free to move from place to place. Also, the existence of the latent heat of fusion and of sublimation shows that in the solid state the molecules are in positions of minimum potential energy and hence of stable equilibrium.

But we can show, also, that the molecules in a solid are arranged in definite directions as well as in definite positions, which means, of course, that the atoms are in definite positions. We shall point out below that the structure of all solids is crystalline, so anything which we prove for crystals will hold for all solid matter. Now it is evident that to form any regular crystal structure the molecules must be arranged in a regular order. But it is generally accepted that the crystal form is some function of the chemical constitution. Unless, however, the atoms in the molecule are arranged in a definite order, it is hard to see how the crystal form can be influenced by the chemical composition. As a matter of fact, a definite arrangement of the atoms in crystals is assumed in the explanation of many of the properties of matter. For example, Lord Kelvin, in explaining pyro- and piezo-electricity (Poynting and Thomson, " Electricity and Magnetism "), assumes that the molecules in the crystals which show this effect have their parts arranged in a certain definite manner, as described below (p. 27). Likewise Bridgman, in explaining the phenomenon of polymorphism under high pressures, says (*Phys. Rev.*, iii, p. 199): " It seems natural that the crystalline form assumed under the free action of the orienting forces is one in which the potential energy of the attractive forces is a minimum; that is, that the local centres of attraction within the molecule have approached as close as possible to each other. If the molecules are forced to assume a different arrangement, even one occupying less volume, these centres of attraction must be pulled apart, and work done against the attractive forces while decreasing the volume. That is, the internal energy of the form with the smaller volume will be the greater." Also, it may easily be shown that the explanation of the expansion of certain substances on solidification depends upon the existence of local centres of attraction within the molecules. It is possible to imagine systems in which the arrangement which would bring the local centers of attraction nearest together would not be the arrangement of minimum volume, so that when the molecules would be in stable equilibrium the volume might be a maximum. Indeed, it is difficult to see how there can be any other explanation. These local centres of attraction, however, can be nothing other than atoms or groups of atoms. We shall see below (p. 11) that if the orienting forces are the attractions between the atoms, such a position of the molecules in the solid state is very easily accounted for. It seems evident, therefore, that in order to explain the crystal structure the molecules must be oriented in such a manner as to give to each atom a definite position.

Aside from this evidence that atoms in crystals have their positions defined, we have further evidence that the atoms in any solid oscillate about definite centres of stable equilibrium. According to the theory of the equipartition of energy, each degree of freedom of an atom in the solid state should possess the same average kinetic energy as a degree of freedom of an atom in the gaseous state at the same temperature. But if we give to each atom in the solid state three degrees of freedom, the specific heat of the atom calculated from the rate of increase of the kinetic energy is only half that which corresponds to Dulong and Petit's law for the atomic heat. Since an atom is supposed to have but three degrees of freedom, in order to account for this difference it is necessary to ascribe to each degree of freedom of the atom potential energy as well as kinetic energy, which increases as the temperature, to give the atom the proper amount of specific heat. But the existence of this potential energy means that the atom is vibrating about a position of stable equilibrium. As the kinetic energy of the atom accounted for half the specific heat, the potential energy must account for the other half, and must therefore be equal, on the average, to the kinetic energy. This indicates that the motion of an atom is, in general very nearly harmonic motion about a central position.

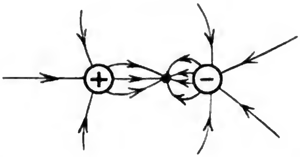
In the explanation of heat radiation, also, we have an indication that the atoms oscillate about centres of stable equilibrium. The explanation referred to is the common one that in solids heat waves and long light waves are produced chiefly by the oscillation of the atoms in harmonic motion about positions of stable equilibrium. Thus from two different lines of evidence we come to the conclusion that the atoms in any kind of a solid must oscillate about positions of stable equilibrium.

THE NATURE AND MAGNITUDE OF THE INTERMOLECULAR FORCES.

The next question is, What is the nature of the forces which hold the atoms in position? This will become evident as we discuss the phenomenon of the cohesion of solids. The accepted molecular theory explains cohesion as due to the settling of the molecules into positions of stable equilibrium, where they are held by the intermolecular forces. It is evident, on the kinetic theory, that the collisions of each molecule with the neighboring molecules will be very frequent in the solid state. But we can show that when two molecules are in "contact" the attraction between atoms of the different molecules is of the same nature and of the same order of magnitude as the attraction between the atoms of the same molecule. This is evident from a consideration of the forces which occur in chemical action. For instance, the fact that some compounds are dissociated when they are dissolved in water implies that the atoms in the water molecules exert a greater force on the atoms of the compound than these do on each other. Similarly when two molecules interact directly, as in an organic reaction in which dissociation takes no part, the atoms of one molecule must exert a greater force on certain atoms in the second molecule than do the other atoms of the second molecule. In fact, the universality of reversible reactions shows that in every case there is a delicate balance between the forces binding an atom to its own molecule and the forces tending to make it join the molecule with which it is in contact. There can be little doubt, therefore, that at least while two molecules are in contact the forces between their atoms are not only of the same nature but also of the same order of magnitude as the forces binding together the atoms of a chemical molecule. (It might be thought at first that this theory of attraction between the atoms of different molecules is opposed to the theory of chemical valency which would seem not to allow an atom to attract more other atoms than it has chemical bonds. According to Stark's theory (Campbell, "Modern Electrical Theory," p. 341), which is possibly as good as any explanation yet offered of the mechanism of valency, a chemical combination between two atoms is not a direct attraction of one atom for another, but a simultaneous attraction of both atoms for the same electron, which thus forms a bond between them. This common electron is one which originally belonged to the electropositive atom, but which was more strongly attracted by the electronegative atom, and on being brought nearer to this atom has the effect of giving it a negative charge and of giving the electropositive atom a positive charge. This method of binding may be illustrated by Fig. 3.

(According to Stark, the band spectra of substances represent the vibrations of the electrons concerned in chemical combination, which are, of course, these "valency" electrons. The fact that the spectrum bands widen as the pressure of the gas increases indicates that these electrons are influenced by neighboring atoms as well as by the atoms of their own molecule. This suggests that the valency electrons may not be fixed in position, but that their positions may be altered by the presence of other molecules. So, if another molecule should come near the first, we might expect them to be held together in some such manner as shown in Fig. 4.

FIG. 3.



(Since the electronegative atom acts as though negatively charged, and the electropositive atom as though positively charged, on account of the position of the valence electron, it is easy to see how a whole system of atoms may be held together, due to the electrostatic forces. For example, when two molecules composed of oppositely charged atoms come together, a position of stable equilibrium is as illustrated in Fig. 5. If two more come near, a position of stable equilibrium is as shown in Fig. 6, which is the elementary cube of an alkali halide. It seems probable that if the equivalent charge and the diameter of every atom were known it might be possible in this way to calculate the different crystalline forms of every compound.)

FIG. 4.

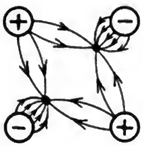
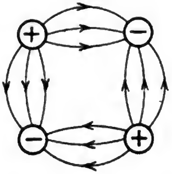
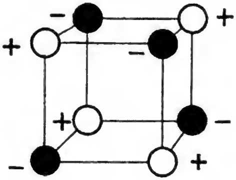


FIG. 5.



Since, therefore, we know that the forces between atoms of different molecules are of the same nature and of the same order of magnitude for at least a considerable portion of the time as those binding a molecule together it is natural to assume that these forces are always similar. Evidence that the forces between the atoms of different molecules are, in general, comparable with the forces between atoms of the same molecule results from a consideration of the atomic heat of substances in the solid state. We found above that in order to explain the specific heat of an atom in the solid state it was necessary to assign to it three degrees of freedom. This is true in whatever way the atom may be combined chemically, so long as the substance obeys Kopp's extension of the Dulong-Petit law. According to the Staigmüller-Boltzmann theory, however, in the gaseous state an atom has no degrees of freedom along its chemical bonds. In order, therefore, that in the solid state it shall have three degrees of freedom, the attractions of the atoms of the neighboring molecules must loosen the chemical bonds enough to allow other degrees of freedom. But in order to do this these attractions must be at least of the same order of magnitude as the forces binding the atom to its own molecule.

FIG. 6.



If, as we have assumed above from a consideration of the Dulong-Petit law, an atom in the solid state has degrees of freedom along its chemical bonds, an atom on the surface of a solid ought, according to the law of velocity distribution, to break away occasionally from the solid as in sublimation. A single atom subliming in this manner should carry with it either a positive or a negative change,[2] so that we should expect the vapor from a subliming solid to be partially ionized. The proportion of the ionized atoms would, of course, be relatively small, since it would be much easier for a group of atoms forming a gaseous molecule to leave the solid than for a single atom, which would be held back by an opposite charge in the solid. Moreover, even though an atom in the *interior* of the solid may have three degrees of freedom, it is easily possible that at the *surface* of the solid, since all the attractions are from one side, the atom might be held firmly to the other atoms so as not to be free to escape. If this be true, it should be possible to show that in the form of very thin foil a substance has smaller specific heat than when in lumps. But even in this case it would seem that an atom on the surface of a solid should not be held as firmly along its chemical bond as it would be in the gaseous state. So we should expect a vapor to become ionized at a lower temperature when in contact with its solid than when not in contact. Is it possible that this is the explanation of the production of thermions from hot salts?

There is evidence, also, from an altogether different source that the forces which hold the molecules of a solid in positions of stable equilibrium are the attractions of the neighboring atoms, and are comparable in magnitude with the forces between the atoms of the same molecule. A measure of the forces holding the atoms together in a molecule is the total heat of combination. Also, since a substance melts when its molecules attain kinetic energy enough to tear them away from the neighboring molecules, the melting-point may be taken as a rough measure of the firmness with which the molecules are held together in the solid. We should expect, therefore, if the firmness with which the molecules are held together depends upon the same properties of the atom as the firmness with which the atoms are held together in the molecule, that the melting-point should vary roughly as the heat of combination.

In order to test this prediction fairly it must be remembered that the melting-point of a solid must depend to some extent upon the arrangement of the atoms in the molecule as well as upon the magnitude of the attractions between the different atoms. Also, it seems very probable that at the melting-point only a definite proportion of the molecules escape from positions of stable equilibrium, the rest remaining in small groups forming "liquid crystals." (This is the explanation that is given for the expansion of water below four degrees. The high specific heat of liquids in general may be explained as due to the latent heat of fusion of these "liquid crystals" as they melt with rising temperature.) It is probable that the relative number of molecules which have sufficient kinetic energy to escape from the positions of stable equilibrium is different for different substances at their melting-points, which would also indicate that the melting point is only a rough measure of the stability of a molecule in a solid. Moreover, the heat of combination is not an absolute measure of the stability of the molecule, for, in the first place, this varies with the stability of the different atoms in the elemental state; *e.g.*, CO_2 from amorphous carbon has a heat of formation of 97.3 × 103, while from diamond it is only 94.3 × 103. In the second place, the heats of formation of substances differ relatively at their melting-points and at room temperature. In view of these and other disturbing factors, we have no reason to expect more than a rough agreement between the atomic heats of formation and the melting-points of the different substances.

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[2] This statement, of course, assumes that the substance is a polar compound, in which case the atoms carry electric charges. If the combination is non-polar, no such evaporation of ions could occur. This is possibly the reason why the emission of thermions of atomic size is confined to the strongly polar compounds, such as the alkali and alkaline earth halides.

In testing this prediction I have grouped similar compounds together, since one would expect that the atomic arrangement of such compounds in the solid state would be similar (see Table I).

TABLE I.

Showing Relation Between the Melting-points (m.p.) and the Atomic Heats of Formation (A.H.F.) of Various Substances.

(*A*) ALKALI HALIDES, ETC.

Substance	A.H.F.	m.p.	Substance	m.p.	Substance	m.p.
KCl	53×10^3	770	KBr	750	KI	723
NaCl	49	801	NaBr	765	NaI	695
LiCl	47	600				
HgCl	15.5	500				
AgCl	14.5	460	AgBr	427	AgI	540
HCl	11	−111	HBr (4)	−86	HI (−3)	−51

(*B*) BICHLORIDES, BROMIDES AND IODIDES.

Substance	A.H.F.	m.p.	Substance	m.p.	Substance	m.p.
($BaCl_2$		960)	$BaBr_2$	880	BaI_2	740
$SrCl_2$	62	825	$SrBr_2$	630		
$CaCl_2$	57	780	$CaBr_2$	760	CaI_2	740
$MgCl_2$	51	708				
$BeCl_2$		600	$BeBr_2$	601		
$PbCl_2$	28	447				
$HgCl_2$	18	290	$HgBr_2$	244	HgI_2	241
$CuCl_2$	17	498				

(*C*) TRI-HALIDES.

Substance	A.H.F.	m.p.	Substance	m.p.	Substance	m.p.
$BiCl_3$	23	227	$BiBr_3$	215		
$SbCl_3$	23	73	$SbBr_3$	93	SbI_3	167
$AsCl_3$		−18				
PCl_3		−112				
$FeCl_3$	24	301				
$AlCl_3$	$24+10^3$	301	$AlBr_3$	93	AlI_3	185
$GaCl_3$		73				
$TlCl_3$		25				

(*D*) ALKALI, ETC., SULPHATES, CARBONATES AND NITRATES.

Substance	A.H.F.	m.p.	Substance	A.H.F.	m.p.	Substance	A.H.F.	m.p.
K_2SO_4	49	1070	K_2CO_3	47	880	KNO_3	24	345
Na_2SO_4	47	884	Na_2CO_3	45	849	$NaNO_3$	22	313
Li_2SO_4	48	853	Li_2CO_3		710	$LiNO_3$	22	258
Tl_2SO_4	32	632						
H_2SO_4	27	10.4				HNO_3	8	−47
Ag_2SO_4	24	676				$AgNO_3$	6	218

(*E*) ALKALI-EARTH, ETC., SULPHATES, CARBONATES AND NITRATES.

Substance	A.H.F.	m.p.	Substance	A.H.F.	m.p.	Substance	A.H.F.	m.p.
$BaSO_4$		infus.	$BaCO_3$		795	$Ba(NO)_2$		575
$CrSO_4$		dec. w.ht.	$SrCO_3$	dec.	1160	$Sr(NO_3)_2$		645
$CaSO_4$	53	v. high	$CaCO_3$	54	dec. r. ht.	$Ca(NO_3)_2$	27	561
$PbSO_4$	38	937				$Cu(NO_3)_2$	9	114.5

(*F*) OXIDES.

Substance	A.H.F.	m.p.	Substance	A.H.F.	m.p.	Substance	A.H.F.	m.p.
MgO	71.5×10^3	over 2000	Cu_2O	14	rd. ht.	SO_3	26	14.8
SiO_2	60	1600	NO_2	− .6	−10	H_2O	23	0
P_2O_5	53	subl. r. ht.	N_2O	−6.3	−102	CO	14.5	−207
Al_2O_3	30	wht. ht.	CaO	70	infus.	Bi_2O	4	84
PbO	25	rd. ht.	B_2O_3	55	577	Cl_2O	−6	−19
SO_2	23	−76	CO_2	32	−65	NO	−11	−167

(*G*) OXIDES AND SULPHIDES.

Substance		m.p.	Substance		m.p.	Substance		m.p.
Sb_2O_3		rd. ht.	H_2O	(23)	0	Bi_2S_3		decomp.
Sb_2O_5		300	ZnO		V. high	CS_2	(−6)	−110
Bi_2O_3		860	Sb_2S_3		fusible	H_2S	(1)	−86
CO_2	(32)	−65	Sb_2S_5		fusible	ZnS		1050

The heat of formation used is that of a gramme-molecule, divided by the number of atoms, thus giving what may be called the "atomic heat of formation." It will readily be seen, by a glance at the tables, that in general the higher the heat of formation the higher the melting-point of a substance. There are a few exceptions to the rule, but the discrepancies are small, and there can be no doubt that the rule holds in general. For instance, if we take the alkali chlorides, the decrease in melting-point is regular, except for a slight variation in sodium, and so, also, as we pass from the chlorides to the bromides and iodides; similarly with the sulphates, carbonates, and nitrates. Among the oxides there are a great number of exceptions, but the predominance of high melting-points at the head of the list and of low melting-points at the foot shows that the general rule holds. Moreover, when the sulphides and the oxides are compared, the former invariably have the lower melting-point, as they should. In order to show that these uniform results are not confined to elements of the same periodic group, Table II and the graph with it have been made, showing all the compounds in the order of their

TABLE II.

The Melting-points of Different Substances in the Order of Their Atomic Heats of Formation.

—Substance	A.H.F.	Authority	m.p.	—Substance	A.H.F.	Authority	m.p.
			C°				C°
ThO_2	110×10^3	3	infus	B_2O_3	55	1	577
UO_2	85	5	2176	TiO_2	54		1500
Al_2O_3	79	1	2040	$CaCO_3$	54	2	1289
MgO	72	1	>2000	$CaSO_4$	53	2	>1000
CaO	70	1, 2	1995	P_2O_5	53		*850
$BaCl_2$	66	2	960	KCl	53	1, 2	770
SrO	65	1, 2	3000	$MgCl_2$	51	2	708
V_2O_5	63	5	658	K_2SO_4	49	1, 2	1070
$SrCl_2$	62	1, 2	825	NaCl	49	1, 2	801
SiO_2	60	1	1600	$LiSO_4$	48	2	853
ZrO_2	59	7	2500	WO_3	48	7	*800
$CaCl_2$	57	2	780	Na_2SO_4	47	1, 2	884

* = approximate value.

TABLE II. (*Continued*)

—Substance	A.H.F.	Authority	m.p.
			C°
LiCl	47	2	600
K_2CO_3	47		880
MnO	45		*1500
Na_2CO_3	45	1, 2	849
MoO_3	45	5	759
As_2O_5	42	2	960
Fe_3O_4	40	4	1538
Fe_2O_3	39	18	1458
$PbSO_4$	38	2	937
$CdSO_4$	37	2	$>$1000
LiOH	37		*850
KOH	35	1, 2	360
NaOH	34	1, 2	318
FeO	32	18	1419
K_2O	32		*800
Na_2O	32		*800
Tl_2SO_4	32	2	632
$ZnCl_2$	32	1, 2	375
CO_2	32	1, 2	−65
TeO_2	29	5	*600
Co_3O_4	28	5	750
$PbCl_2$	28	2	447
$Ca(NO_3)_2$	27	1	561
$SnCl_2$	27	2	249
H_2SO_4	27	2	10
SO_3	26		15
$SnCl_4$	26		−33
PbO	25	2	*800
Ag_2SO_4	24		676
TlCl	24	2	407
KNO_3	24×10^3	1, 2	345
$FeCl_3$	24	2	01
$BiCl_3$	23	2	227
$SbCl_3$	23	2	73
SO_2	23		−76
$NaNO_3$	22	1, 2	313
$LiNO_3$	22	2	258
$CdCl_2$	21	2	568
Tl_2O	21	2	300
SeO_2	21	5	$>$ 260
$AlCl_3$	20		190
NOCl	− 2	9	− 60
HI	− 3	1, 2	− 51
H_2Se	− 5		− 64
N_2O_3	− 5	1	−106
Cl_2O	− 6		− 19
CS_2	− 6	1	−110
N_2O	− 6		−112
AsH_3	− 9		−113
HCN	−10		− 14
NO	−11	2	−167
C_2H_2	-12×10^3	2	− 82
C_2N_2	−19	1	− 35
SbH_3	−22	1	− 91
H_2O	19	1	0
$(NH_4)_2SO_4$	19	1, 2	140
CuO	19	2	1148
$HgCl_2$	18		290
$CuCl_2$	17		498
HgCl	15		500
CCl_4	15	1	− 24
Cu_2O	14		*800
Tl_2O	14		*700
AgCl	14	1, 2	460
PbI_2	14	6	373
CO	14		−207
C_2H_5COOH	11	2	− 22
HCl	11	2	−111
$Cu(NO_3)_2$	9		114
AgI	8	13	500
HNO_3	8	1	− 47
CH_3OH	8	2	− 95
Trifluorocresol	7	17	− 5
C_2H_5OH	7×10^3	2	−112
CH_3CHO	7	2	−120
$AgNO_3$	6	1, 2	218
Nitrofluorophenol	5	17	74
$CHCl_3$	5	2	− 70
$(C_2H_5)_2O$	5	2	−117
Fluoronitracetanilide	4	17	96.5
Bi_2O_3	4		84
Parafluorphenol	4	17	28
Orthofluorphenol	4	17	16
Metafluorphenol	4	17	14
HBr	4	2	− 86
CH_4	4	1, 2	−184
Metafluoracetanilide	3	17	85
Difluorethylnitramine	3	17	45
Nitrofluorphenetol	3	17	14
Metatrinitrotoluol	3	17	− 2.4
Parafluorphenetol	3	17	− 8.5
C_2H_6	3	1, 2	−171
C_3H_8	3	2	−195
NH_3	3		− 75
Parafluornitrobenzol	2	17	27
Ethylenitramine	2	17	6
SiH_4	2		$<$ 0
Fluornitraniline	1	17	96
Dinitrofluorbenzol	1	17	26
Metafluornitrobenzol	1	17	4
H_2S	1	2	− 86
Metacresol	+ .3	17	4
C_7H_8	− .1	2	− 97
C_2H_4	− .3	2	−169
NO_2	− .6	1	− 10
C_6H_6	−1	2	5
Aniline	−1	2	− 8

* = approximate value.

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"atomic heats of formation." Here there is no chance for any other factor, such as atomic weight or place in the periodic table, to affect the melting-points consistently. I have not made any selection, but have used all the compounds for which the required data are available. In spite of occasional rather large discrepancies in this table, there can be no doubt that in general the melting-point rises with an increase in the atomic heat of formation.[3]

I have given so much space to this demonstration of the connection between the heat of combination and the melting-point because this seems to be a definite proof that the forces which bind the atoms of different molecules together in the solid state, measured by the melting-point, are similar to those which bind a chemical molecule together, measured by the atomic heat of combination. The similarity must be not only a likeness in nature, but also comparability in magnitude, since if the magnitude of the forces were not comparable there would be no reason to expect the relative melting-points to be comparable with the relative heats of formation.[4] We may consider it established,

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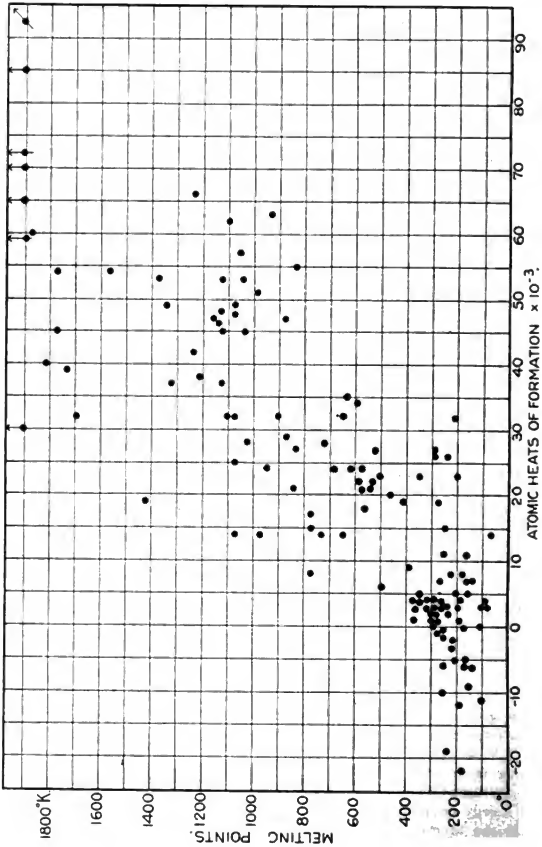
[3] Table II and the graph representing it (Fig. 7) are more complete than those given in the original paper. They were shown in their present form before the American Physical Society at its meeting October 30, 1915.

[4] A calculation of the energy required to raise the temperature of a substance from absolute zero to its melting-point and melt it shows that, on the average, this energy is about one-fourth of its heat of formation. Thus the energy required to remove the atoms of a "molecule" in the solid form from the atoms of the neighboring "molecule" is of the same order of magnitude as that required to separate the atoms of the same molecule from each other.

Fig. 7.


90
80
70
60
50
40
30
20
10
0
-10
-20
ATOMIC HEATS OF FORMATION $\times 10^{-3}$.
1800°K.
1600
1400
1200
1000
800
600
400
200
0°
MELTING POINTS.

therefore, that in a solid the forces affecting an atom due to neighboring atoms of other molecules are both of the same nature as and comparable in magnitude with the forces due to the other atoms of its own molecule.

It thus appears that the forces of cohesion which hold the molecules in positions of stable equilibrium must be the mutual attractions of the atoms of neighboring molecules. In order, however, that each molecule should be in the most stable position with respect to the other molecules, it is evident that it must orient itself in such a manner that the atoms of different molecules which attract each other most strongly shall be next to each other. One result of this is that the molecules must evidently all be oriented and arranged in a definite, repeating order, which means a crystalline structure. Thus we see that the structure of all true solids must be crystalline. If this is true, the molecules in the so-called "amorphous solids" must not be in positions of most stable equilibrium under the atomic forces, and these substances should therefore have neither a definite melting-point nor perfect elasticity even for small forces. It seems probable that the "near solid state" in which these substances exist is caused by the agglomeration of large numbers of molecules into minute crystalline groups, similar to liquid crystals, which are so large compared with their distances apart that the viscosity is very great.

A second result of this arrangement of the molecules is that since an atom is nearest the other atoms of its own molecule which attract it most strongly, and since it comes next to the atoms of the neighboring molecules which attract it most strongly, it seems probable that, wherever possible, the arrangement of the atoms on all sides of it shall be similar. So if an atom should escape from the other atoms of its own molecule it would be held just as strongly by the atoms of the other neighboring molecules.

The forces on an atom due to the atoms of its own molecule and to those of other molecules, on the average, equal.

The next step in the argument to prove that there is no true molecular structure in the solid state will be to show that the forces between the atoms of the different supposed molecules are as great as those between the atoms of the same molecule. The first part of this proof is to show that the distance between the atoms in a solid is small compared with the "diameters" of the atoms themselves. That is, if the atoms are considered as spheres, the distance between the surface of two neighboring spheres is small compared to their diameters.

Possibly the most direct way to show this point is to compare the size of the molecules as deduced (1) from the viscosity of a gas, (2) from the thermal conductivity, and (3) from Van der Waals's equation, with the size of the molecules as deduced from the density of the densest known form of the substance, assuming the molecules to be spheres arranged in the order of closest packing. As we saw above, according to the Staigmüller-Boltzmann theory, the atoms of a molecule in the gaseous state are in such close contact that there is no freedom for motion along a chemical bond. So if it can be shown that the molecules are very nearly in contact, the atoms of different molecules must also be very nearly in contact. The following figures are taken from Kaye and Laby's tables, page 33:

Molecular diameter deduced from

	Viscosity	Thermal Conductivity	Van der Waal's Equation	Limiting Density
H_2	2.47 times 10^{-8}	2.40 times 10^{-8}	2.32 times 10^{-8}	2.92 10^{-8}
He	2.18		2.30	4.34
N_2	3.50	3.31	3.53	2.97
O_2	3.39	3.31		2.79
A	3.36		2.86	4.43
Kr			3.14	4.93
Xe			3.42	4.88
C_2H_4	4.55	4.68		5.26
CO_2	4.18	4.32	3.40	4.42
N_2O	4.27	4.20		4.58
H_2O	4.09			3.49

These data assume that the molecules are spherical, which undoubtedly introduces some error, but the uniformly close agreement of the values in the fourth column with those in the other three can leave but little doubt that the molecules in the solid state, and hence the atoms also, must be very nearly in "contact."

In support of this evidence for the proximity of the atoms in a solid we may mention the evidence which comes from the X-ray spectra from different crystals that the distance of the thermal motion is small compared with the diameter of the atoms themselves. This evidence comes from a consideration of the relative intensity of the different orders of spectra. At first the rapid falling off in intensity of the higher orders for such crystals as rock salt when compared with crystals like potassium ferrocyanide was explained as due to the greater heat motion of the lighter atoms in the former case. But the Laue photographs which de Broglie obtained at great extremes of temperature—from liquid air to red heat—showed a surprisingly small difference in the intensity of the spots, showing that the heat motion has very little effect. Apparently the only remaining explanation is that the X-rays are not reflected from single points in the atoms, but by electrons distributed throughout the atoms. Thus it is the size of the atom compared to the distance apart of the reflecting atoms which accounts for the decrease in intensity of the higher orders of spectra. (If a large proportion of the electrons are in the central ring about the nucleus, the intensity should not diminish as rapidly as if they are uniformly distributed throughout the sphere. It should be possible to test this point.[5]) But since the heat motion of the atom does not materially affect the intensity of the higher orders of spectra, while the diameter of the atoms does so affect it, the distance of the heat motion, and hence the distance between the atoms, must be small compared with the diameter of the atoms.

A more definite confirmation comes from the arrangement of the atoms in those simple crystals whose structure has been worked out. If we assume here the existence of molecules, the distance between the atoms within a molecule is the same as that between neighboring atoms of different molecules. The atoms of the same molecule are certainly very near together, however, so for these simple compounds, at least, any two neighboring atoms are very close together.

One further line of evidence toward this same point may be valuable. The expansion of solids on heating is due, of course, to the lengthening of the paths of the molecules as the temperature rises. It seems natural to suppose that at absolute zero the length of these paths would decrease until the molecules come in contact. Even if the coefficient of expansion were constant the volume of a solid would not decrease enough to indicate at ordinary temperatures a free path comparable with the diameter of the atoms. As a matter of fact, at low temperatures the coefficient of expansion approaches zero, which indicates an " agglomeration " into groups in which the atoms are all in contact. This is the same theory of agglomeration as the one used to explain the decrease of specific heat at low temperatures. If this theory is correct, at low temperatures all the atoms, whether of the same or of neighboring molecules, are held in "contact" with each other.[6] We may conclude, then, with considerable certainty that the atoms of neighboring molecules are very nearly in contact with each other, and that they are probably as near together as the atoms of the same molecules.

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[5] It was this fact that suggested the writer's study of the distribution of the electrons in atoms as indicated by the intensity of X-ray reflection (cf. *Nature*, May 27, 1915, and *Phys. Rev.*, **9**, 29, 1917). In the latter paper it was shown that the distance of the outer electrons from the atomic centres was comparable with the distance between the atoms. According to Debye's theory of the effect of heating on the intensity of X-ray spectra (*Ann. d. Phys.*, **43**, 49, 1914), which has been verified experimentally by Professor Bragg (*Phil. Mag.*, **27**, 881, 1914), the thermal motion is relatively small, and reduces to practically zero at very low temperatures, as is here suggested.

We showed above that the forces between atoms are of the same nature, whether due to atoms of the same molecule or to those of different molecules. It seems evident, therefore, that the attraction between atoms should be some function of the distance such that if the distances are equal the forces should also be equal. This is confirmed by the evidence of chemical action which we considered above. But, since we know that the distances between atoms of the same molecule and atoms of neighboring molecules are approximately equal, the forces should likewise be very nearly equal. Thus we see that the forces on all sides of an atom must, on the average, be at least very nearly the same.[5]

We can go still farther and show it to be probable that the forces on an atom due to the atoms of neighboring molecules are, on the average, exactly equal to the forces from the other atoms of its own molecule. From the discussion in the last paragraph we see that an atom is as strongly attracted to another atom with which it is in contact, though of a different molecule, as it is to a similar atom in its own molecule. When, therefore, due to the heat motion of a molecule in the solid, one of its atoms comes in contact with an unlike atom of a different molecule, there are even chances that it will remain fast to the other molecule. So in a very large number of collisions it will belong just as much of the time to one molecule as it will to the other, and so cannot be said to be a part of either. As a matter of fact, since we know, from a study of the Dulong-Petit law, that an atom has three degrees of freedom in a solid, and since an atom cannot remain joined to another without losing a degree of freedom (Staigmüller-Boltzmann Theorie), it is evident that an atom cannot remain in contact for more than an infinitesimal interval with another atom, but must continually oscillate back and forth, exerting equal attractions on all the neighboring atoms.

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[6] The theory referred to is that suggested by C. Benedicks (*Ann. d. Phys.*, **42**, 133, 1913).

The fact that Dulong and Petit's law is not accurately followed—*i,e.*, that the atoms of solids do not always have three degrees of freedom, is a support rather than an objection to our hypothesis; for as the temperature decreases, the time interval during which an atom remains in contact with a neighboring atom will, on the average, increase, thereby decreasing the total number of degrees of freedom at any one instant. In the gaseous state, as we have just seen, each atom has three degrees of freedom minus the number of its chemical bonds. But if the gas is heated to a sufficiently high temperature it becomes ionized; that is, the chemical bonds become loosened so that parts of the molecule occasionally separate (Meyer, "Kinetic Theory of Gases," p. 132). According to our hypothesis, when a molecule assumes the solid state, the attractions of the neighboring atoms loosen the chemical bonds sufficiently to give each atom three degrees of freedom. Even in the solid state, however, each atom is strongly bound to the neighboring atoms, so that if the kinetic energy of the atom should become sufficiently low, one would expect it to be held in contact with some of the other atoms thus taking away its degrees of freedom, until it should be moved from its place by a sufficiently violent collision. This would be exactly analogous to the binding of the atoms together in a gas molecule until there is a sufficiently violent collision to ionize the gas. The only differences are that, since the atom in the solid state is not held so strongly by other atoms, the collisions would not have to be so violent, and that, since the atom in the solid state is surrounded by other atoms, it might have either zero, one or two degrees of freedom when held in contact with other atoms. It is easy to see that on this hypothesis, when the kinetic energy becomes sufficiently low, large numbers of the atoms will be held in contact with each other, thus losing their degrees of freedom, so that as absolute zero is approached the specific heat should also approach zero. This is, I believe, about the same as the " Agglomeration Theorie " on which Dean Magie reported to Physics Colloquium last winter.[7]

CONCLUSION.

THE STRUCTURE OF SOLIDS IS NOT MOLECULAR.

Since, therefore, each atom of a substance in the solid state exerts equal forces on all the neighboring atoms, it cannot be said definitely to belong or not to belong to the same molecule as some other one atom.[8] In other words, the atoms of a solid are so intimately intermingled that particular molecules cannot be definitely defined. Thus we can no longer speak of solid matter as having a molecular structure, but must consider it to be purely atomic, which is the thesis we started to prove.[9]

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[7] These were the considerations which led to the development of the theory of specific heat presented by the writer in the *Physical Review*, **6**, 377, 1915, where it was found that this agglomeration hypothesis is capable of explaining in a fairly satisfactory manner the variation of the specific heat of solids with temperature. It may be pointed out that the theories of the temperature variation of specific heat based on the quantum hypothesis (Einstein, Nernst-Lindemann, Debye) lead to the same conclusion as that here arrived at concerning the rigidity with which atoms are held in a solid. According to these theories, the energy corresponding to a degree of freedom depends upon the corresponding frequency of vibration. In the case of gases this frequency is very high, while in the solid state the frequency of the natural vibrations of the atom is relatively low. This means that the rigidity with which the atom is held in position is much less in the solid state than in the gaseous state, due doubtless to the fact that the forces due to the surrounding atoms are nearly equal on all sides.

[8] On account of the selective nature of the forces between atoms, we can state these forces as a function of the distance only when we consider but a single arrangement of the atoms. This argument therefore proves that the "bonds" on the different sides of an atom are of the same strength only for those atoms which have similar atomic groups arranged symmetrically about them. For this reason it is probable that there are some complicated compounds in which certain groups of atoms may retain their identity in the solid state. The writer has been unable to think of any substance, however, which could crystallize in such a manner that some one atom would not be equally strongly bound to two or more similar atomic groups. The molecule is therefore indeterminate, inasmuch as this particular atom cannot be said to belong to one atomic group rather than to another.

A CONSIDERATION OF OBJECTIONS.

As an immediate result of our hypothesis it must follow that matter in the solid state can have no properties which depend upon a molecular structure as distinguished from an atomic structure. It is important, therefore, to consider those explanations of properties of solid matter which involve a molecular structure. All such explanations which I have been able to find are those which consider solid matter to be made up of electric or magnetic doublets. For instance, there is the common explanation of electric strain as due to molecules in the dielectric which are made up each of two portions, one positively, the other negatively electrified, and that the two portions are shifted by the forces accompanying the strain. Of course, in making this assumption chemical and electric attraction are identified, as we have assumed

FIG. 8.

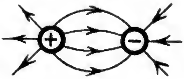
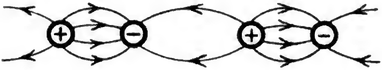


FIG. 9.



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[9] Langmuir's conclusion from similar considerations is rather that the crystal is a single molecule. The difference depends chiefly upon whether the molecule is defined as the smallest portion of a substance which has the characteristics of the substance or as a group of atoms held together by chemical forces. The above argument is based on the former definition, contending that these smallest portions cannot be definitely defined. Langmuir concludes, on the basis of the latter definition, that, since all the atoms in a crystal are similarly bound together, the whole crystal is a single molecule. Since, however, the forces of cohesion and adhesion are essentially identical with chemical forces, a similar argument would show that the whole earth, and perhaps even the whole universe, is a single molecule. The writer therefore prefers the former conception of the molecule as having a more definite meaning.

above. Following Poynting and Thomson (" Electricity and Magnetism," p. 59): " We may, for our present purpose, . . . conventionally represent a molecule as in the figure (Fig. 8) . . . If the dielectric is in a neutral condition, we must suppose that the molecular axes are distributed equally in all directions, . . . and there is no resultant electric action outside." When an electric field is imposed, these molecules arrange themselves as in Fig. 9, which has the same effect as placing a charge on the surfaces of the dielectric.

FIG. 10.

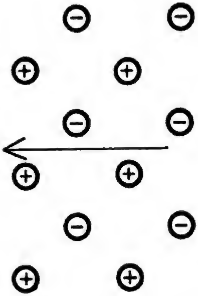
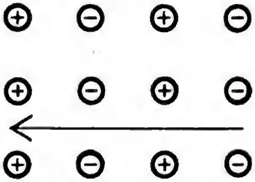
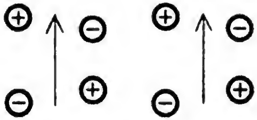


FIG. 11.



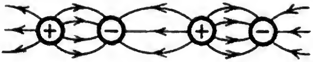
If this means that the molecules are capable of rotation through any angle, then in a crystal such as a KCl crystal, if the electric field were perpendicular to the (111) planes, as in Fig. 10, the supposed molecules would arrange themselves as in Fig. 11. Thus the (111) planes would become cleavage planes, which is evidently absurd, since there is no apparent change in the crystal structure. But if the theory means only that a molecule can be turned slightly from its stable position, there is nothing which requires a true molecular structure, since a slight shift in the position of the atoms will produce the same result. (If this shift in position is great enough, it should be possible to detect it in crystal dielectrics by obtaining X-ray spectra from them. For example, if the electric field is perpendicular to a cleavage plane of a KCl crystal, we might expect the atoms to be displaced as in Fig. 12. It may be shown that such a displacement would reduce the comparative intensity of the higher orders of spectra, and this, by careful measurement, might be noticeable.)

FIG. 12.



Another explanation of electric phenomena which apparently depends upon a true molecular structure in a crystal is Lord Kelvin's explanation of pyroelectricity, which is also extended to piezoelectricity. As explained in Poynting and Thomson ("Electricity and Magnetism," p. 150), this explanation is: "The molecules are set in the crystal with their electric axis parallel to a certain direction, and there will therefore be a definite amount of strain passing from each positive element of a doublet to the negative element of the doublet next to it. The crystal, as a whole, will be the seat of an electric strain along the direction of the axis. The constitution corresponds to that of a saturated permanent magnet on the molecular theory of magnetism. The electric strain will manifest itself almost entirely at the ends of the crystal if the doublets are near enough together, and the crystal will produce a field outside equal to that which would be produced by charges respectively positive and negative at the two ends. . . . But . . . charges will in time gather on

FIG. 13.



the surfaces at the ends of the axis, . . . entirely masking the existence of the strain, so that there is no external field. This is the ordinary condition of a neutral crystal.

"We have now to suppose that the electric strain passing forward from molecule to molecule depends on the temperature, and that it alters nearly in proportion to the change in temperature. Then when the temperature changes there will be an unbalanced strain proportional to the change, producing the same effect as a positive charge at one end and a negative charge at the other until conduction again does its work in bringing up masking charges."

FIG. 14.

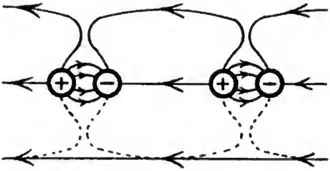
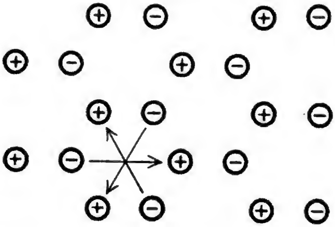


FIG. 15.



The mechanical model which Poynting and Thomson suggest as an illustration is a series of molecular doublets, arranged as illustrated in Fig. 13, which, when heated, assume the arrangement shown in Fig. 14 as the molecules become separated. Here certain of the lines of force combine, giving the effect of a free charge at either end. This model would explain pyroelectricity as due merely to molecular separations, and we ought to get a similar effect if the molecular separation is produced by tension, which is the piezoelectricity found by Curie.

An objection to this model is that it assumes that as the temperature rises the parts of the molecule come relatively closer together, while experiments in specific heat seem to indicate that with rising temperature the parts of a molecule become farther separated. A model to which this objection does not apply, which does not assume any molecular structure, and which accords fully with Kelvin's explanation, may easily be imagined. Suppose the atoms in a crystal to be arranged as in Fig. 15. It will be seen at once that such an arrangement will correspond to the " saturated permanent magnet on the molecular theory of magnetism." The left end will have the equivalent of a positive charge and the right end that of a negative charge. There will evidently be in this model three different axes along which there will be such an effect, which might correspond to the three electric axes of a quartz crystal. As the atoms move farther apart with a rise in temperature the strength of the doublets is increased, and, if the ends were neutralized before, a new charge will now appear.

Of course, the same result would occur here also if the atoms were separated by tension, which would explain piezoelectricity. If the structure of a quartz crystal can be determined as the Braggs are now trying to do, it will be an easy matter to see whether a true molecular structure is required for the explanation of pyro- and piezo-electricity.

There are, however, some difficulties with a complete explanation of the magnetic properties of solids, without assuming a molecular structure, that are not so easily met. One of the arguments for a molecular structure from magnetic properties comes from a consideration of the Heusler alloys. In these alloys no element by itself is very strongly dia- or para-magnetic, but when the different elements are alloyed the mixture is almost as paramagnetic as iron. From this it might be concluded that atoms from two different slightly magnetic substances can combine to form a molecule that is ferromagnetic.

We have, however, strong indications that magnetism is a purely atomic property. A good experimental indication of this comes from depositing iron electrolytically in a magnetic field. For instance, if a varnished silver wire with a thin scratch through the varnish is placed in a solution of ferric chloride, when the iron is deposited electrolytically an extremely small magnetic field will make of the deposited iron a saturated magnet. This indicates that the elementary magnetic doublets are easily turned around while the iron is being deposited. The iron is deposited, however, atom by atom, and, since the position taken by each atom is determined by the crystal form and not by the magnetic field, it must be the atoms and not the molecules which are oriented by the magnetic field.

Perhaps the strongest evidence that the magnetic effects are not molecular but atomic phenomena is the fact that the structure of the atom which the most generally accepted theories suggest offers an excellent explanation of magnetism as due to atomic properties. I refer to the theory that the atom consists of electrons revolving in orbits, held together by the appropriate positive charge. This, of course, makes each atom an elementary magnetic doublet. Langevin and Weiss have developed a complete theory on this assumption (Professor Richardson's lectures on "Electron Theory"), explaining both dia- and para-magnetism, which seems to be as satisfactory as any yet proposed. The fact that a theory based on this assumption explains magnetic phenomena so well without any reference to a molecular structure would indicate that these effects have no dependence on molecular structure.

However, we have good reason to believe that the environment of an atom greatly influences its magnetic properties. For instance, different samples of iron vary greatly in their magnetic properties, according to their temper, per cent. of carbon, amount of alloy, temperature, etc. The explanation of Heusler alloys would therefore seem to be that the environment of the atoms of the different elements is changed in such a manner by being alloyed that they are free to turn under a magnetic field.

There is another difficulty, however, which results from a purely atomic explanation of magnetism. This is an explanation of the heating effect when a piece of iron is placed in an alternating magnetic field. This alternating magnetic field, if intense enough, is supposed to turn the elementary doublets completely around. If these doublets are molecular, it is easy to see how their turning can impart kinetic energy to the system and so raise the temperature; but if they are atomic, since only the translational degrees of freedom of an atom are supposed to possess heat motion, any amount of rotation of the atom would not affect the temperature of the substance. Two possible explanations may be offered. In the first place, it is possible that, since an atom can no longer be considered to be a sphere, its rotary degrees of freedom actually do enter into the thermal motions. Or, in the second place, though the rotary degrees of freedom may not themselves enter into the heat motion, it is possible, since the atoms are not spheres, that their rotation may displace other atoms translationally, which would account for the heating effect. It must be confessed, however, that neither of these explanations appears wholly satisfactory, and that this heating effect presents a real difficulty to any non-molecular explanation of magnetic phenomena.

A test for this point would be to take Laue photographs through a crystal such as pyrrhotite, which shows magnetic effects, and see if there is any change in the internal structure when the crystal becomes saturated.[10]

SUMMARY.

To sum up our argument then: It is shown, in the first place, that the arrangement of the atoms in certain crystals, as determined by their X-ray spectra, indicates definitely that in these crystals there is no molecular structure.

In extending the argument to all solid matter it is pointed out, from the dependence of crystal form on chemical composition, from a consideration of the Dulong-Petit law and of the nature of cohesion, and from the evidence of X-rays as to certain crystals, that each atom in a solid oscillates about a definite position of stable equilibrium.

From a further examination of the nature of cohesion and of the forces concerned in chemical combination and especially from the general relation found between the atomic heat of formation of a substance and its melting-point it is found that the forces holding the atoms in their positions of stable equilibrium are of the same nature and comparable in magnitude with the forces binding together a chemical molecule.

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[10] This test was suggested by my brother, K. T. Compton. It has been made by K. T. Compton and E. A. Trousdale (*Phys. Rev.*, **5**, 315, 1915) and repeated with greater care by the writer and Oswald Rognley (*Science*, N. S., **46**, 415, 1917). These experiments show that when magnetic crystals are saturated magnetically the atoms are not displaced by as much as 1/250 of the distance between the atoms. Magnetic effects are therefore not due to rotations of the molecules, but must be due to the atoms or something within the atoms.

It is seen further that the atoms in a solid are very close together, so that they often come in contact. And, since an atom attracts equally all atoms of another kind which are in contact with it, an atom cannot remain combined for more than an infinitesimal interval with any other particular atom at ordinary temperatures.

Finally, it was shown that, since in the solid state each atom has three degrees of translational freedom and is strongly attracted by atoms other than those of its own "molecule," it must, on the average, exert equal attractions on all the neighboring atoms.

From this the conclusion is drawn that in the solid state the atoms are so intimately intermingled that particular molecules cannot be definitely defined.

When those properties of solid matter which have been explained by molecules are considered, nothing is found which indicates at all definitely a molecular structure.

We feel justified in concluding, therefore, *that the structure of solid matter is not molecular.*

July 25, 1914.

Largest High-head Francis Turbine. ANON. (*Electrical Review*, vol. 72, No. 10, p. 417, March 9, 1918.)—The Puget Sound Traction, Light and Power Company, of Seattle, Wash., is installing a new turbine unit of 25,000 horsepower capacity in its White River hydro-electric plant in the vicinity of Sumner, Wash. The two original units, which were installed in 1911, have a rated capacity of 36,000 horsepower, but in actual practice have carried a load of 44,000 horsepower. This equipment, which includes Francis turbines, was built by the Allis-Chalmers Manufacturing Company, the plant having been designed and installed under the supervision of Stone & Webster, engineers. The new installation is being made primarily to supply the power required by the Chicago, Milwaukee and St. Paul Railway Company to operate passenger and freight trains over the Cascade Mountain division in Washington.

The new unit being installed consists of equipment similar to that of the two units now in use; the new Francis turbine, however, having a capacity of 25,000 horsepower, is the largest of this type ever built. The turbines of the two original units are of the double-discharge horizontal type with spiral case, operating at 360 revolutions per minute under a head of 440 feet. These turbines have shown very high efficiency under test.

THE EFFICIENCY OF LIGHT-PRODUCTION IN ORGANISMS.*

BY

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The production of light by organisms has always been a subject of much comment by men who are interested in the economics and mechanism of light-production.

It is therefore well to consider what the efficiency of this process may be, judging, as we must, from what the efficiencies are, in general, of energy transformations in the organic world. It is frequently stated that the efficiency of light-production by the firefly is very high—inferred without foundation from the fact that the energy radiated by it is highly concentrated in a band in the visible spectrum; or from this in conjunction with the fact that an insect possesses relatively very great strength.

The luminous efficiency of the radiation from the firefly is 97 per cent. This efficiency, however, is merely one element in the whole process of light-production. There are several processes whose efficiency must be reckoned also, and which may tell us more concerning the light-source than this.

A few general considerations will make this clear.

Let $e_{l.r.}$ represent the luminous efficiency of the radiation. Then by definition we have $e_{l.r.} = \frac{L}{R}$; where R is the energy radiated at all wave-lengths, both visible and invisible, and L is the energy radiated in the visible portions of the spectrum after being reduced at each wave-length to some arbitrary unit of luminosity,

$$\text{or } L = KV$$

$$\text{and } R = V + r = \frac{L}{K} + r$$

where K is the mean value of the visibility,[1] V is the radiant power in the visible portion of the spectrum, and r is the radiant power in the non-visible parts of the spectrum.

$$\text{Then } e_{l.r.} = \frac{L}{\frac{L}{K} + r} = \frac{1}{\frac{1}{K} + \frac{r}{L}} = \frac{K}{1 + \frac{r}{V}}$$

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* Communicated by the Author.

Now $K \leqq 1$, if we choose as the unit of visibility that at wave-length of maximum visibility (0.555μ).

According to this equation, $e_{l.r.}$ may have values from 0 to 1 when $K = 1$, and from 0 to K when $K < 1$. When $K = 1$, all the energy of the spectrum lies at wave-length of maximum visibility. In order that $e_{l.r.}$ may be large, say greater than 50 per cent., the amount of energy in the infra-red must be less than that in the visible region.

These considerations hold generally for common light-sources and for luminescence produced by other means. However, there may arise some unusual property of the light-source or some unusual conditions under which the measurements are made that will render the value of $e_{l.r.}$ much more difficult of interpretation.

As examples of such cases may be instanced the luminescence produced in a chemical reaction which is endothermic. If we imagine determinations of $e_{l.r.}$ made by means of a radiometer (a thermopile and galvanometer) we will obtain a certain deflection (say positive) when the visible portion only is considered by interposing a "luminosity screen" between the light-source and the sensitive surface of the radiometer; while the deflection we obtain as a measure of the total energy radiated may even be negative, if the reaction were sufficiently endothermic to allow the light-source to absorb more energy from the thermopile than it radiates upon it. Logically, then, we have for our defining

equation $$e_{l.r.} = \frac{1}{\frac{1}{K} - \frac{r}{L}} = \frac{K}{1 - \frac{r}{V}}$$

Under the conditions postulated $e_{l.r.}$ may have any value between $+\propto$ and $-\propto$.

An instance [2] of an endothermic reaction producing luminescence is that of iodide of Mellon's base. It has never been determined whether the reaction producing the light in organisms is endothermic or exothermic.

Conditions postulated above wherein negative values of $e_{l.r.}$ are obtained may be realized in a manner other than by endothermic reactions giving light. The luminescence given by bodies when kept at liquid air temperature would show ostensibly the same effects.

No data are available from which the efficiency of any energy transformations in insects may be approximated. However, the efficiency of energy transformations in the insect is probably of the same magnitude as that in case of higher animals about which more data are at hand.

The popular conception that the insect is very much more efficient in transforming food energy into mechanical energy than a mammal is based upon the idea of the " strength " of the insect. For example, an ant can carry many times more its own weight than an elephant, and a grasshopper can leap many more times its own length than a kangaroo. In all such instances, however, we are not taking account of the total energy involved, but are referring to the speed of utilization of energy of a stored substance. In the cases cited there is probably normally involved only the speed of oxidation of glucose in the muscle-cells; while the production, transportation, and storage of the glucose or glycogen is not involved at the moment the extraordinary movements are made.

In support of the assumption that the efficiency of the physical and chemical processes maintaining in organisms does not vary widely from the insecta to the mammalia may be noted some comparative data pertaining to the process of respiration.[3]

In the following table is given the ratio between the oxygen expired as carbon dioxide and the oxygen inspired as air for various creatures:

Bee	0.81	Rabbit	0.92
Fly	1.14	Dog	0.74
Sparrow	0.79	Horse	0.91
Hen	0.90	Man	0.78
Mouse	0.80	Lizard	0.75
Guinea Pig	0.86	Frog	0.80
Carp	0.66	Starfish	0.78
Octopus	0.86		

This ratio is very sensitive to temperature changes,[4, 5] and large discrepancies that exist can probably be accounted for.

In a general way there is the efficiency of each of two steps in the energy transformation in organisms to be considered: First, the efficiency of food intake and of its transformation into the final product, and of storing the final product for subsequent use; second, the efficiency of taking from storage and utilizing the final substance for the production of muscular and other forms of energy.

If we designate the numbers representing these efficiencies by e_p and e_u respectively, then the total efficiency is $e_p \times e_u$. The efficiency of production of the final substance and the efficiency of utilization of the substance in the firefly are unknown, as in all cases of light-production by organisms. The corresponding values for the transformation of the energy in gas and in the electric current into mechanical energy are as follows:

For gas e_p is 66.5 per cent.—made of two factors of producing and storing the gas, 70 per cent., and for distributing the gas to the motor, 95 per cent. The efficiency, e_u, of the gas motor may be 25 per cent. The efficiency of the whole process is $e_u \times e_p =$ 16.6 per cent.

Similarly for the electric current we have $e_p = 11.9$ per cent. roughly—made of the two factors of producing the electric current and bringing to the buss-bars, 13 per cent., and for distributing to the motor, 92 per cent. The efficiency of the electric motor may be taken as 95 per cent. So that the efficiency of the whole process becomes $e_p \times e_u = 11.3$ per cent.

When we come to consider the transformation of the energy into light there enter the efficiencies of still further steps relating to the radiation of the energy. We may very conveniently now look upon e_u as made up of two parts: First, the total amount of energy radiated with reference to the total available energy; second, the amount and quality of this radiated energy lying in the visible region of the spectrum.

The latter is the lighting or luminous efficiency of the radiation. In case of the firefly this is 97 per cent.—exceedingly high compared with that of ordinary light-sources. The luminous efficiency of the radiation from a Welsbach mantle lamp is 0.476 per cent., and of that from the tungsten filament lamp is 1.65 per cent., while that of the yellow flame arc is 13 per cent.

The former is the radiating or radiational efficiency. This, in case of the firefly, as in all organisms producing light, is unknown. For the Welsbach lamp it is 25 per cent., for the tungsten lamp 90 per cent. Sources of losses that will make the radiating efficiency low may be either physical or chemical.

The efficiency of the production of light by an organism, reckoned from the time the light-giving substance begins to react, is given by $e_{l.r.} \times e_r$; where $e_{l.r}$ has been previously defined, and e_r. is the radiating efficiency.

The efficiency of the whole process of light-production is given by $e_l = e_p \times e_r \times e_{l.r.}$ The value of this product is not known for many light-sources other than the ordinary gas and electric lamps.

For the Welsbach gas lamp the value of e_l is 0.08 per cent., and for the tungsten electric lamp it is 0.13 per cent.; where the constituent parts of e_l are as follows:

	e_p	e_r	$e_{l.r.}$	e_l
Electric	0.09	0.90	0.0165	0.0013
Gas	0.67	0.25	0.0048	0.0008

Any single one of the factors tells us little, as we have seen above. The numbers given in the table are merely intended to give an idea of the magnitudes that may be or are attained. In practice they vary considerably, depending upon the size of the gas or electric plant.

In the product of these factors e_p is not known for the firefly. However, an idea may be gotten of a permissible magnitude of it from a consideration of the magnitude of the efficiency of other processes carried on by organisms. This is the chief purpose of this paper.

There has been some excellent work done upon the strength of insects, but it is to be regretted that in most cases the results are only qualitative or the necessary data have not been recorded. As an instance of the strength of insects may be cited that of a large beetle (*Passalus cornutus Fob.*). This beetle is 1.1 cm. across and 3.3 cm. long, and weighs 1.04 g. The following numbers are the ratios of the weight of the load to the weight of the insect and express the strength of the insect in various attitudes:

Horizontal pull upon wood	19.66
Horizontal pull into furrow	158.73
Vertical pull	10.0
Lifting strength by head:	
(*A*) By promesothoracic muscle alone	35.4
(*B*) By aid of forelegs, too	122.8

The beetle crawled with a weight of 700 g. upon its back.

During the time of working the beetles lost 2.89 per cent. of their weight, as compared with 0.62 per cent. in control beetles.

The author concludes that there is no relation between the loss in weight to the work done. It is to be regretted, however, that he fails to record the amount of work done.

These data are the nearest approach to what is necessary in order to calculate the efficiency of transformation by an insect of the chemical energy in a stored substance (probably glycogen) into mechanical energy. This would give e_u as defined above.

Some partial data, but insufficient, for the common housefly[9] (*Muscæ domesticus*) and for the boll-weevil[10] may be found.

For data regarding the transformation of the energy of the food into energy other than mechanical, one would naturally look to the cow among the higher animals and to the bee and silkworm among the insects. In each of these cases the chemical energy in one substance is transformed into chemical energy in another substance—the energy of the grain into chemical energy of the milk; the energy of the pollen and sugar into that of wax; the energy of the mulberry leaf into the energy of the silk.

With these instances of energy transformation of such tremendous importance to mankind it is surprising to find such a meagreness of data regarding them.

In an experiment[11] with bees it has been found that 12 g. of cane-sugar produced 1 g. of wax. The amount of fats and nitrogen compounds experienced no change during the progress of the experiment, so that we have here an excellent example of transformation of chemical energy in food to that in a secreted substance.

The energy content of sugar is 1860 cal./g. The energy content of the wax is more uncertain. The heat of combustion of unrefined beeswax is 16492 B.t.u. per lb. (9043 cal./g.). Here the efficiency of the energy transformation is 40.5 per cent.

In another experiment[12] 1250 g. of honey, together with 117 g. of pollen, made 84 g. of wax. When the bees were fed 1250 g. of honey alone only 51 g. of wax was produced. Let us assume, then that 117 g. of pollen produced 33 g. of wax.

The heat of combustion of pollen varies probably, and it is not known what pollen was used in the experiment.

The heat of combustion of ragweed pollen * as recently determined is 8776 B.t.u./lb. The heat of combustion of beeswax is 16492 B.t.u./lb. Therefore for this transformation we have the efficiency equal to 5.3 per cent.

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* The ragweed pollen was kindly supplied by the Upjohn Chemical Company, Kalamazoo, Mich.

Honey is not a true secretion, but the nectar of plants after having been acted upon by some of the secretions of the bee. This fact should be manifested by an extremely high efficiency.

The insect world offers us another prominent example in the silk-moth whose larva produces the silk. Silk is a true secretion and is formed from the mulberry leaves devoured by the silkworm.

We have some data [13] available relating to the production of silk by the silkworm for a given quantity of leaves consumed, but the data lacking for our calculation are the heat of combustion of mulberry leaves and that of the silk.

It has been estimated [14] that about 18 per cent. of the energy of the feed is transformed into energy of the milk by the cow. While about 24 per cent. of the energy of the grain is transformed and stored in pork, only 3.5 per cent. is stored in beef and mutton.

These figures are e_p, defined above, for these organisms. Even if e_u be very high, the product of the two will be low. Of the magnitude of this product we may judge by comparison with results of the determinations of the mechanical efficiency of the horse and of man. In the former [18] the net efficiency is often above 30 per cent. In the latter [19] it may also be nearly as high under the best conditions of speed and coördination; while for slow-speed performances and under ordinary conditions it is very much lower.

The last figures are for the net efficiency; the gross efficiency is considerably lower. For example, the gross efficiency for a man riding a bicycle is 16.1 per cent.,[20] while the net efficiency is 24.9 per cent.

The net efficiency is derived by deducting from the total energy input the energy that is necessary to keep the organism in a normal condition, or in a zero position as regards the performance under question.[20]

We may infer, then that if the product of e_u and e_p for the firefly is 20 per cent., it is a probable value, though perhaps a high net value as the efficiency of energy transformations in the organic world run.

The efficiency of the light-production by the firefly, then, is 19.4 per cent.

We are assuming that e_r is 100 per cent.; *i.e.*, that there are no losses by conduction and convection, or by the formation of chemical compounds, when the reaction producing the light takes place.

The "mechanical equivalent" of light is 49.1 candles per watt.[21, 22] We have an efficiency expressed in ordinary units of 0.1 watt per candle.

From a consideration of the relative size of the firefly and the proportion of tissues producing the light it has been estimated that the efficiency is 0.054 watt per candle.[23]

The energy of the light from all sources considered comes from the sun. Let us consider the species of firefly that is herbiverous. The plant stores as chemical energy between one and two per cent. of the energy of the sun falling upon its leaves.[24] If we also consider that much of the sun's energy is lost in the earth's atmosphere,[24] we find that about 0.19 per cent. of the original solar energy is given back as light by the firefly. By the use of coal and gas or electric lamps the fractional part of the original solar energy that is obtained as light again is of the order of 0.0007 per cent. This figure is certainly too large, for no allowance for the waste of coal by erosion was made, nor was the whole of the earth's surface considered.

All the figures which have been given above hold only for the lapse of time of our experiment and become appreciably less when longer intervals are considered—the hours of activity as well as the hours of rest, the night as well as day, and all seasons and ages.

The most important sources of information regarding the subject-matter discussed above are given in the bibliography below, some of which have not been directly referred to in the text.

I am indebted to Mr. W. H. Fulweiler for the determination of the heating value of beeswax and pollen. I wish also to express my appreciation to friends in many departments of science whose suggestions and attention have been invaluable.

PHYSICAL LABORATORY,
The United Gas Improvement Co.,
February 23, 1918.

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Rail-creep. F. REEVES. (Proceedings, Institution of Civil Engineers through *Scientific American Supplement*, vol. 85, No. 2202, March 16, 1918.)—Rail-creep has been commonly believed to be caused mainly by temperature changes, assisted by the movement of trains. Experiments made several years ago by the author indicate that the primary cause is the deformation of the rails under the rolling loads, assisted by temperature changes, which cause fish-joints to slip and lessen the resistance. The first experiments consisted in passing a wooden wheel several times in succession, in one direction, over a planed white-pine lath resting on a hardwood bench.

The lath was found to have moved bodily about two millimetres in the direction of travel, the total amount of the latter having been about fourteen metres. Further experiments were made not only with pine laths but also with flat iron bars on side and on edge, and with a strip of India rubber. The conclusion drawn from these experiments is that creep is due primarily to deformation of the rail as the wheel passes over it. With the pine lath the creep was always from twice to four times the amount when the lath was supported on sleepers. The effect was heightened when the lath was on the flat as compared with the same lath on edge.

Where track is on a yielding roadbed, creep is intensified, especially under heavy wheel loads. It is also accentuated by braking in places where regular stops are made. On single lines there is normally no trouble with creep, but if there is any great preponderance of traffic in one direction, more or less creep takes place in that direction. It is easy to reduce creep to a small amount by putting in anchors, but is is not easy to suppress it entirely on double lines under modern conditions. In double track the outer rails (the rails near the edge of the ballast) move more than the inner. There would be little harm in creep if all the track were " open track " and both rails " ran " equally. Where it compels preventive measures is at connections with other lines, junctions, sidings, crossovers, etc. The only practical way to anchor track is over long stretches and through numerous sleepers.

Dam Sites on the Missouri River in South Dakota. D. ROBINSON. (South Dakota Department of Immigration, January, 1918.)—The extent of the undeveloped water powers in the United States and the limitations to their utilization have long been appreciated by hydraulic engineers and economists, but the stress of war-time conditions resulting in an extraordinary fuel shortage has brought the subject prominently into view and aroused a widespread appreciation of the importance of utilizing available sources of water power. A study of possible dam sites for power projects along the Missouri River within the boundaries of South Dakota is a notable example of an increasing interest in the subject.

South Dakota is peculiarly fortunate in the natural formation of the Missouri River valley which makes it possible to construct a considerable number of water powers upon that stream. This is a resource peculiar to South Dakota, when at frequent intervals the river-walls of the immediate valley of the stream approach each other so closely as to make the erection of dams feasible. The minimum discharge of the Missouri in the northern part of South Dakota is 10,000 second-feet. It rarely, if ever, reaches this minimum. The average discharge is 24,833 second-feet for the entire year, and the average for the growing season is 37,500 second-feet. The combined minimum effected power developable at seven sites suggested is 242,000 horsepower. The average flow of the stream will produce at the same heads 552,000 horsepower.

PHYSICS OF THE AIR.*

BY

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CHAPTER XIV.

THE THUNDERSTORM.

Introduction.—A thunderstorm, as its name implies, is a storm characterized by thunder and lightning, just as a dust storm is characterized by a great quantity of flying dust. But the dust is never in any sense the cause of the storm that carries it along, nor, so far as is known, does either thunder or lightning have any influence on the course—genesis, development, and termination—of even those storms of which they form, in some respects, the most important features. No matter how impressive or how terrifying these phenomena may be, they never are anything more than mere incidents to, or products of, the peculiar storms they accompany, as will be made clear by what follows. In short, they are never in any sense either storm-originating or storm-controlling factors.

Origin of Thunderstorm Electricity.—Many have supposed that, whatever the genesis of the thunderstorm, the lightning, at least, is a product or manifestation of the free electricity always present in the atmosphere—normal atmospheric electricity. Observations, however (discussed later), seem definitely to exclude this assumption. Thus, while the difference in electrical potential between the surface of the earth and a point at constant elevation is, roughly, the same at all parts of the world, the number and intensity of thunderstorms vary greatly from place to place. Further, while the potential gradient at any given place is greatest in winter, the number of thunderstorms is most frequent in summer, and while the gradient in the lower layer of the atmosphere, at many places, usually is greatest from 8 to 10 o'clock, both morning and evening, and least at 2 to 3 o'clock P.M. and

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* Continued from page 647, vol. 185, May, 1918.

3 to 4 o'clock A.M., no closely analogous relations hold for the thunderstorm.

But how, then, is the great amount of electricity incident to a thunderstorm generated? Fortunately an answer to this question based on careful experiments and numerous observations, and that greatly aids our understanding of the interrelations between the various thunderstorm phenomena, has been given by Dr. G. C. Simpson,[83] of the Indian Meteorological Department.

Doctor Simpson's observations, just referred to, were made at Simla, India, at an elevation of about 7000 feet above sea-level, and covered all of the monsoon seasons, roughly, April 15 to September 15, of 1908 and 1909. He also made observations of the electrical conditions of the snow at Simla during the winter of 1908–9.

A tipping bucket rain gauge gave an automatic, continuous record of the rate and time of rainfall, while a Benndorf [84] self-registering electrometer marked the sign and potential of the charge acquired during each two-minute interval. A second Benndorf electrometer recorded the potential gradients near the earth, and a coherer of the type used in radiotelegraphy registered the occurrence of each lightning discharge.

All obvious sources of error were examined and carefully guarded against. Hence it would seem that the conclusions drawn from the thousands of observations given in the memoir are fully justified; and especially so since several independent series of similar observations made at different times, by different people, and at places widely separated, have given confirmatory results in every case. Simpson's records show that—

(1) The electricity brought down by the rain was sometimes positive and sometimes negative.

(2) The total quantity of positive electricity brought down by the rain was 3.2 times greater than the total quantity of negative electricity.

(3) The period during which positively charged rain fell was 2.5 times longer than the period during which negatively charged rain fell.

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[83] Memoirs, Indian Meteorl. Dept., Simla, 1910, **20**, pt. 8; *Phil. Mag.*, **30**, 1, 1915.

[84] *Physikal. Ztschr.*, Leipzig, 1906, **7**, 98.

(4) Treating charged rain as equivalent to a vertical current of electricity, the current densities were generally smaller than 4×10^{-15} amperes per square centimetre; but on a few occasions greater current densities, both positive and negative, were recorded.

(5) Negative currents occurred less frequently than positive currents, and the greater the current density the greater the preponderance of the positive currents.

(6) The charge carried by the rain was generally less than 6 electrostatic units per cubic centimetre of water, but larger charges were occasionally recorded, and in one exceptional storm (May 13, 1908) the negative charge exceeded 19 electrostatic units per cubic centimetre.

(7) As stated in paragraph (3) above, positive electricity was recorded more frequently than negative, but the excess was the less marked the higher the charge on the rain.

(8) With all rates of rainfall positively charged rain occurred more frequently than negatively charged rain, and the relative frequency of positively charged rain increased rapidly with increased rate of rainfall. With rainfall of less than about 1 millimetre in two minutes, positively charged rain occurred twice as often as negatively charged rain, while with greater intensities it occurred 14 times as often.

(9) When the rain was falling at a less rate than about 0.6 millimetre in two minutes, the charge per cubic centimetre of water decreased as the intensity of the rain increased.

(10) With rainfall of greater intensity than about 0.6 millimetre in two minutes the positive charge carried per cubic centimetre of water was independent of the rate of rainfall, while the negative charge carried decreased as the rate of rainfall increased.

(11) During periods of rainfall the potential gradient was more often negative than positive, but there were no clear indications of a relationship between the sign of the charge and the sign of the potential gradient.

(12) The data do not suggest that the negative electricity occurs more frequently during any particular period of a storm than during any other.

Concerning his observation on the electrification of snow Doctor Simpson says:

So far as can be judged from the few measurements made during the winter of 1908–9, it would appear that—

(1) More positive than negative electricity is brought down by snow in the proportion of about 3.6 to 1.

(2) Positively charged snow falls more often than negatively charged.

(3) The vertical electric currents during snowstorms are, on the average, larger than during rainfall.

While these observations were being secured a number of well-devised experiments were made to determine the electrical effects of each obvious process that takes place in the thunderstorm.

Freezing and thawing, air friction, and other things were tried, but none produced any electrification. Finally, on allowing drops of distilled water to fall through a vertical blast of air of sufficient strength to produce some spray, positive and important results were found, showing:

(1) That breaking of drops of water is accompanied by the production of both positive and negative ions.

(2) That three times as many negative ions as positive ions are released.

Now, a strong upward current of air is one of the most conspicuous features of the thunderstorm. It is always evident in the turbulent cauliflower heads of the cumulus cloud—the parent, presumably, of all thunderstorms. Besides, its inference is compelled by the occurrence of hail, a frequent thunderstorm phenomenon, whose formation requires the carrying of raindrops and the growing hailstones repeatedly to cold and therefore high altitudes. And from the existence of hail it is further inferred that an updraft of at least 8 metres per second must often occur within the body of the storm, since, as experiment shows,[85] air of normal density must have approximately this upward velocity to support the larger drops, those of 4 mm. or more in diameter, and, because of its greater weight, even a stronger updraft to support the average hailstone.

Experiment also shows [86] that raindrops of whatever size can not fall through air of normal density whose upward velocity is greater than about 8 metres per second, nor themselves fall with greater velocity through still air; that drops large enough, 4.5 mm. in diameter and up, if kept intact, to attain through the action of gravity a greater velocity than 8 metres per second with reference to the air, whether still or in motion, are so blown to pieces that the increased ratio of supporting area to total mass causes the resulting spray to be carried aloft or, at least, left behind, together with, of course, all original smaller drops. Above sea-level this limiting velocity is greater. It is given approximately by equating the weight of the drop, $4/3\ \pi\ r^3 g\ (\rho - \sigma)$, to the supporting force, $\pi\ r^2\ \sigma\ v^2$, roughly, in which r is the radius of the drop, ρ its density, σ the density of the air, v the velocity in question, and g the gravitational acceleration. Hence the limiting velocity increases in practically the same ratio that the square-root of the density decreases. Thus at an elevation of 3 kilometres above sea-level, where the barometric pressure is about 520 mm. and the temperature, say, 15° C. lower than at the surface, the limiting velocity is approximately 9.4 metres per second, instead of 8, the value for normal density, or density at 0° C. and 760 mm. pressure. Clearly, then, the updrafts within a cumulus cloud frequently must be strong and therefore break up at about the same level, that of maximum rain accumulation, innumerable drops which, through coalescence, have grown beyond the critical size, and thereby, according to Simpson's experiments, produce electrical separation within the cloud itself. Obviously, under the turmoil of a thunderstorm, such drops may be forced through the cycle of union (facilitated by any charges they may carry) and division, of coalescence and disruption, from one to many times, with the formation on each at every disruption, again *according to experiment*, of a correspondingly increased electrical charge. The turmoil compels mechanical contact between the drops, whereupon the disruptive equalization of their electrical potential breaks down their surface tensions and insures coalescence. Hence, once started, the electricity of a thunderstorm rapidly grows to a considerable maximum.

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[85] P. Lenard, *Met. Zeit.*, vol. 21, p. 249, 1904.

[86] P. Lenard, *Met Zeit.*, vol. 21, p. 249, 1904.

After a time the larger drops reach, here and there, places below which the updraft is small—the air cannot be rushing up everywhere—and then fall as positively charged rain, because of the processes just explained. The negative electrons, in the meantime, are carried up into the higher portions of the cumulus, where they unite with the cloud particles and thereby facilitate their coalescence into negatively charged drops. Hence the heavy rain of a thunderstorm should be positively charged, as it almost always is, and the gentler portions negatively charged, which also very frequently is the case.

Such in brief is Doctor Simpson's theory of the origin of the electricity in thunderstorms, a theory that fully accounts for the facts of observation and in turn is itself abundantly supported by laboratory tests and imitative experiments.

If this theory is correct—and it seems well founded—it must follow that the one essential to the formation of the giant cumulus cloud—namely, the rapid uprush of moist air—is also the one essential to the generation of the electricity of thunderstorms. Hence the reason why lightning seldom occurs except in connection with a cumulus cloud is understandable and obvious. It is simply because the electrifying process of splashing is vigorously active in this cloud and nearly absent in others.

The occasional lightning in connection with snowstorms, dust storms, and volcanic eruptions may in each case be due to the fact that the collision of solid particles produces electrification.[87]

The Violent Motions of Cumulus Clouds.—From observations, and from the graphic descriptions of the few balloonists and aviators who have experienced the trying ordeal of passing through the heart of a thunderstorm, it is known that there is violent vertical motion and much turbulence in the middle of a large cumulus cloud, a fact which, so far as it relates to the theory alone of the thunderstorm, it would be sufficient to accept without inquiring into its cause. However, to render the discussion more nearly complete, it perhaps is worth while, since it is a mooted question, to inquire what the probable cause of the violent motions in large cumulus clouds really is—motions which, in the magnitude of their vertical components and degree of turmoil, are never exhibited by clouds of any other type nor met with elsewhere by either kites or balloons of any kind, manned, sounding, or pilot.

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[87] Rudge, *Proc. Roy. Soc., A*, **90**, 256, 1914.

It has been shown by von Bezold[88] that sudden condensation from a state of supersaturation, and also sudden congelation of undercooled cloud droplets, would, as a result of the heat thus liberated, cause an equally sudden expansion of the atmosphere, and thereby turbulent motions analogous to those observed in large cumuli. However, as von Bezold himself points out, it is not evident how either the condensation or the freezing could suddenly take place throughout a cloud volume great enough to produce the observed effects. Besides, these eruptive turmoils, whatever their genesis, undoubtedly originate and run their course in regions already filled with cloud particles in the presence of which no appreciable degree of supersaturation can occur. Hence the rapid uprush and the violent turbulence in question obviously must have some other cause, which indeed is provided by the difference between the actual temperature gradient of the surrounding atmosphere and the adiabatic temperature gradient of the saturated air within the cloud itself.

Consider a warm summer afternoon, temperature 30° C., and assume the dew-point to be 18° C. Now, the adiabatic decrease of temperature of non-saturated air is about 1° C. per 100 metres increase in elevation, and therefore, under the assumed conditions, vertical convection of the surface air causes condensation to begin at an elevation of approximately 1.5 kilometres—allowing for the increase of volume per unit mass of vapor. From this level, however, so long as the cloud particles are carried up with the rising air, the rate of temperature decrease for at least a couple of kilometres is much less—at first about one-half the previous rate. After a considerable rise above the level of initial condensation, half a kilometre, say, the raindrops have so increased in size as to lag behind the upward current and even to drop out, while at the same time the amount of moisture condensed per degree fall of temperature grows rapidly less, as shown by the saturation adiabats of Fig. 60. Hence for both reasons—because the heat of the water is no longer available to the air from which it was condensed, the drops having been left behind, and because a decreasing amount of latent heat is to be had from further condensation, there being less and less precipitation per degree cooling—the rate of temperature decrease again approaches the adiabatic gradient of dry air, or 1° C. per 100 metres change of elevation.

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[88] *Sitzber. K. preuss. Akad. d. Wiss.*, Berlin, 1892, **8**, 279–309.

Obviously, then, for some distance above the level at which condensation begins to set free its latent heat the temperature of the rising mass of moist air departs farther and farther from the temperature of the surrounding atmosphere at the same level, and therefore its buoyancy for a time as steadily increases. But, of course, as explained above, this increase of buoyancy does not continue to any great altitude.

In the lower atmosphere continuous and progressive convection builds up the adiabatic gradient so gradually that no great difference between the temperature of the rising column and that of the adjacent atmosphere is anywhere possible. Hence, under ordinary conditions, the uprush in this region is never violent. But whenever the vertical movement of the air brings about a considerable condensation it follows, as above explained, that there is likely to be an increase in its buoyancy, and hence a more or less rapid upward movement of the central portion, like air up a heated chimney, and for the same reason, together with, because of viscosity, a rolling and turbulent motion of the sides, of the type so often seen in towering cumulus clouds. Obviously, too, the uprushing column of air must continue to gain in velocity so long as its temperature is greater, or density less, than that of the surrounding atmosphere, except as modified by viscosity, and therefore have its greatest velocity near the level at which these two temperatures are the same. Hence the rising column must ascend somewhat beyond its point of equilibrium, and then, because slightly undercooled, correspondingly drop back.

Fig. 82, based upon approximately average conditions, illustrates the points just explained. The elevation is in kilometres and the temperature in degrees Centigrade.

AB is the adiabatic temperature gradient for non-saturated air, about 1° C. per 100 metres change in elevation. *GCKDEF* is the supposed temperature gradient before convection begins, or a decrease, in accordance with observations, of 6° C., about, per kilometre increase in elevation, except near the surface, where the temperature decrease, before convection has begun, ordinarily is less rapid, and at elevations between 5 kilometres, roughly, and the isothermal level, where it is more rapid.

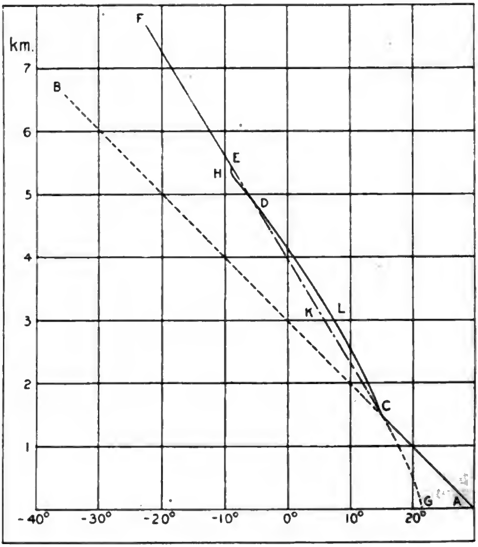
As convection sets in, the temperature decrease near the surface soon approximates the adiabatic gradient for dry air, and this condition extends gradually to greater altitudes, till, in the given case, condensation begins at the level *C*, or where the temperature is 15° C. Here the temperature decrease, under the assumed conditions, suddenly changes from 10° C. per kilometre increase of elevation to rather less than half that amount, but slowly increases with increase of altitude and consequent decrease of temperature. At some level, as *L*, the temperature difference between the rising and the adjacent air is a maximum. At *D* the temperature of the rising air is the same as that of the air adjacent, but its momentum presumably carries it on to some such level as *H*. Within the rising column, then, the temperature gradient is given approximately by the curve *ACLDHE*, while that of the surrounding air is substantially as shown by the curve *ACKDEF*.

The cause, therefore, of the violent uprush and turbulent condition within large cumulus clouds is the difference between the temperature of the inner or warmer portions of the cloud itself and that of the surrounding atmosphere at the same level as indicated by their respective temperature gradients *CLD* and *CKD*. Clearly, too, while some air must flow into the condensation column all along its length, the greatest pressure difference, and therefore the greatest inflow, obviously is at its base. After the rain has set in, however, this basal inflow is from immediately in front of the storm, and necessarily so, as will be explained later.

The approximate difference in level between *D* and *H*, or the height to which the momentum of the ascending column will force it to rise after it has cooled to the temperature of the surrounding air, may easily be computed in terms of the vertical velocity at *D* and the difference between the temperature gradients of the rising and the non-rising masses of air. Let the vertical velocity of the rising column be *V* centimetres per second at *D*; let the average absolute temperature between D and H be T; and let the difference between the temperature of the rising air and the surrounding air change uniformly at the rate δT per centimetre change of elevation.

Obviously the kinetic energy of the rising air at D will be used up in lifting it to some greater elevation. But the weight of a mass m of this air is not mg (g being gravity acceleration), which it would be *in vacuo*, but $mg\ (\frac{\rho-\sigma}{\rho})$, in which ρ is the density of the air in question and σ the density of the surrounding air. Thus at h centimetres above D $\rho-\delta=\frac{h\,\delta T}{T}\rho$, approximately, and therefore the weight of the mass m at this level $m\,g\,\frac{h\,\delta T}{T}$, approx-

FIG. 82.



Temperature gradients within (CLD) and without (CKD) cumulus clouds.

imately. Hence the work in lifting the mass m through this altitude h is its average weight, $mg\frac{h\,\delta T}{2T}$, multiplied by the distance h.

Hence $\frac{1}{2} m V^2 = m g x^2 \frac{\delta T}{2T}$ or $x^2 = \frac{V^2 T}{g\,\delta T}$

in which x, directly proportional to V, is the height in centimetres to which the air will rise above D.

Let $T = 265°$ C. absolute, corresponding to the conditions shown in Fig. 82; let the temperature gradient be 6° C. per kilometre in the free air and 8° C. per kilometre in the rising air, and δT the temperature change between the two per centimetre change of elevation, therefore 1/50000; and let $V = 12$ metres per second, then

$$x = 1200 \sqrt{\frac{5 \times 10^4 \times 265}{980}} = 1.395 \text{ kilometres.}$$

Since the height of the barometer at an elevation of 5 kilometres above sea-level is, roughly, 400 mm., and since the supporting force of an updraft is proportional to the product of its density by the square of its velocity, it follows that the vertical velocity in metres per second necessary to support the largest drops at this elevation is given by the equation,

$$V = v \sqrt{\frac{760}{400}},$$

in which v is the required velocity at normal density. But, as above explained, $v = 8$ metres per second, about, and therefore $V = 11$ metres per second, approximately.

Hence the above assumption that the vertical velocity at D is 12 metres per second appears to be conservative.

Viscosity between the rising and the adjacent air prevents the actual height attained from being quite equal to the above theoretical value; nevertheless, the maximum elevation, or what might be called the "momentum level" often, especially in the case of the largest and most active cumulus clouds, is much greater than the equilibrium level.

Convectional Instability.—Rapid vertical convection of humid air, as we have seen, is essential to the production of the cumulus cloud and, therefore, to the generation of the thunderstorm. Hence it is essential to consider the conditions under which the vertical temperature gradient necessary to this convection can be established. These are:

> 1. Strong surface heating, especially in regions of light winds; a frequent occurrence.
>
> The condition that the winds be light is not essential, or perhaps even favorable, to the genesis of all thunderstorms—only the local or heat variety, and favorable to these simply because winds, by thoroughly mixing the air, prevent the formation of isolated rising columns, the progenitors of this particular type of storm.
>
> 2. The overrunning of one layer of air by another at a temperature sufficiently lower to induce convection. This apparently is the cause of practically all ocean thunderstorms. It seems also to be the chief cause of those that so frequently occur on land in connection with cyclones.
>
> 3. The underrunning and consequent uplift of a saturated layer of air by a denser layer; a frequent occurrence to a greater or less extent and presumably, therefore, at least an occasional one of sufficient magnitude to produce a thunderstorm.

Here the underrunning air lifts both the saturated layer and the superincumbent unsaturated layer, and thereby forces each to cool adiabatically. But as both layers are lifted equally, while, because of the latent heat of condensation, the saturated layer cools much slower than the dry, it follows that a sufficient mechanical lift of a saturated layer of air would establish between it and the non-saturated layer above a superadiabatic temperature gradient and thereby produce local convection, cumulus clouds, and perhaps a thunderstorm.

Periodic Recurrence of Thunderstorms.—While thunderstorms may develop at any hour of any day, they nevertheless have three distinct periods of maximum occurrence: (*a*) Daily, (*b*) yearly, and (*c*) irregularly cyclic. Each maximum depends upon the simple facts that the more humid the air and the more rapid the local vertical convections the more frequent and also the more intense the thunderstorms, for the obvious reason that it is rapid vertical convection of humid air that produces them.

Daily Land Period.—Vertical convection of the atmosphere over land areas reaches its greatest altitudes and thereby produces the heaviest condensation and largest cumulus clouds when the surface is most heated; that is, during afternoons. Hence the hours of maximum frequency of inland or continental thunderstorms are, in most places, 2 to 4 P.M.

Daily Ocean Period.—Because of the great amount of heat rendered latent by evaporation, because of the considerable depth to which the sea is penetrated by solar radiation, and because of the high specific heat of water, the surface temperature of the ocean increases but little during the day, and because of convection or the sinking of any surface water that has appreciably cooled and the bringing of the warmest water always to the top, it decreases but slightly at night. Indeed, the diurnal temperature range of the ocean surface usually is but a small fraction of one degree C., while that of the atmosphere at from 500 to 1000 metres elevation is several fold as great.[89] Hence those temperature gradients over the ocean that are favorable to rapid vertical convection are most frequent during the early morning hours, and therefore the maximum of ocean thunderstorms usually occurs between midnight and 4 A.M.

Yearly Land Period.—Just as inland thunderstorms are most frequent during the hottest hours of the day, so, too, and for the same reason, they are, in general, most frequent over the land during the hottest months of the year, or rather during those months when the amount of surface heating, and therefore the vertical temperature gradient, is a maximum. This will be better understood by reference to the winter and summer gradients of Fig. 15, determined, as previously explained, by averaging 52 and 65 records, respectively, obtained by sounding balloons sent up from Munich, Strassburg, Trappes, and Uccle, places of about the same latitude and having generally similar climates. It will be seen that the temperature of the air not only is much higher at all levels during summer than during winter, but also decreases through the first three kilometres much more rapidly.

That this important difference between the temperature gradients of winter and summer is general and not peculiar to the above localities is obvious from the fact that during summer the surface of the earth gradually grows warmer and therefore induces correspondingly frequent and vigorous convection, while during winter it as steadily becomes colder and therefore only occasionally, at the times of temporary warming, induces convections strong enough to form large and well-defined cumulus clouds.

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[89] Braak, *Beitr. z. Physik d. fr. Atmosph.*, Leipzig, 1914, **6**, 141.

From these several considerations it is evident that:

a. Winter convections cannot, in general, rise to nearly so great altitudes nor with such velocity as those of summer.

b. The absolute humidity of summer air may at times be greatly in excess of that of winter.

c. The winter snow level usually is much below that of summer.

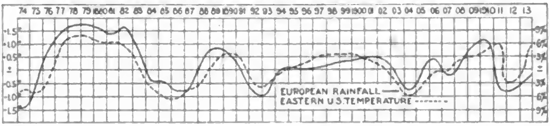
Hence thunderstorms, since they depend, as explained, upon the action of strong vertical convection on an abundance of *rain* drops, necessarily occur most frequently during the warmer seasons, and only occasionally during the colder months. In middle latitudes, where there are no late spring snows to hold back the temperatures, the month of maximum frequency is June. In higher latitudes, where strong surface heating is more or less delayed, the maximum occurs in July or even August.

Yearly Ocean Period.—Over the oceans, on the other hand, temperature gradients favorable to the genesis of thunderstorms, and therefore the storms themselves, occur most frequently during winter and least frequently during summer. This is because the temperature of the air at some distance above the surface, being largely what it was when it left the windward continent, greatly changes from season to season, while that of the water, and, of course, the air in contact with it, changes relatively but little through the year. That is, over the oceans the average decrease of temperature with increase of elevation obviously is least and, therefore, thunderstorms fewest in summer, and greatest, with such storms most numerous, in winter.

Cyclic Land Period.—Since thunderstorms are accompanied by rain and since over land they are most numerous during summer, it would appear that they must occur most frequently either in warm or in wet years and least frequently in cold or in dry years. Further, if it should happen, as it actually does, that, for the earth as a whole, warm years are also wet years and dry years cold years, it would appear logically certain that, for the entire world, the maxima numbers of thunderstorms must belong to the years that are wet and warm and the minima to those that are cold and dry.

A complete statistical examination of these statements is not possible, owing to the fact that meteorological data are available for only portions of the earth's surface and not for the whole of it. Nevertheless, well-nigh conclusive data do exist. The annual rainfall, for instance, to the leeward of a large body of water obviously must bear the same relation to the annual average windward temperature that the total annual precipitation over the entire world does to the annual average world temperature. In each case the amount of evaporation or amount of water vapor taken into the atmosphere, and therefore the amount of subsequent precipitation, clearly must increase and decrease with the temperature. An excellent test and complete support of this deduction is furnished by Fig. 83, in which the full line represents the smoothed annual European precipitation,[90] and the dotted line smoothed annual average temperatures over the eastern United States. Obviously, as supported by the data graphically represented in Fig. 83, the warmer the air as it leaves America the greater the moisture it must take up in its passage across the Atlantic, and therefore the greater its supply of humidity on reaching Europe and the heavier the subsequent precipitation. Clearly, too, the same relations must apply to the entire earth that so obviously should and so demonstrably do hold for the North Atlantic and its adjacent continents.

FIG. 83.



Relation of European rainfall to eastern United States temperature.

Beyond a reasonable doubt, therefore, for the world as a whole, warm years are wet and cold ones are dry. Hence, as above stated, it is practically certain that the maxima of thunderstorms occur during years that are wet, or warm—for the two are synchronous—and the minima during years that are dry or cold. A partial and, so far as it goes, a confirmatory statistical test of this conclusion is given by Fig. 84. The lower group of curves is based on an exhaustive study by Dr. von Gulik[91] of thunderstorms and lightning injuries in Holland. The continuous zigzag line gives the actual number of thunderstorm days, and the continuous curved line the same numbers smoothed. The broken lines give, respectively, the actual and the smoothed values of the annual average precipitation. The upper curve represents the variations in the smoothed number of destructive thunderstorms[92] (number of thunderstorm days not readily available) in Germany.

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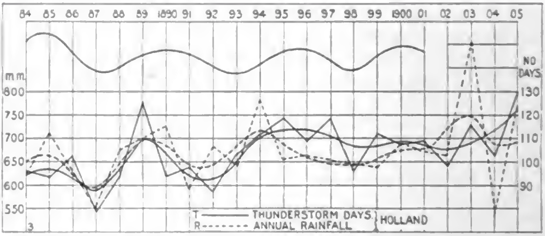
[90] Hellmann, "Die Niederschläge in den Norddeutschen Stromgebieten," Berlin, 1906, vol. 1, pp. 336–337, and elsewhere.

The original data on which this last curve is based indicate a continuous and rapid increase of thunderstorm destructiveness throughout the period studied, 1854–1901. Presumably, however, this increase is real only to the extent that the country has become more densely populated and more thickly studded with destructible property. Since thunderstorms are caused by rapid vertical convection and heavy condensation, and since the temperature of the air upon which these in turn depend has not, on the decade average, measurably changed since reliable records began, at least a hundred years ago, there clearly is no logical reason for believing that the decade average either of the frequency or the intensity of the storms themselves has materially changed during that time. At any rate, this element—that is, the

FIG. 84.



Relation of annual number of thunderstorm days to total annual precipitation—Holland. The uppermost wavy curve shows the variation in the smoothed number of destructive thunderstorms in Germany.

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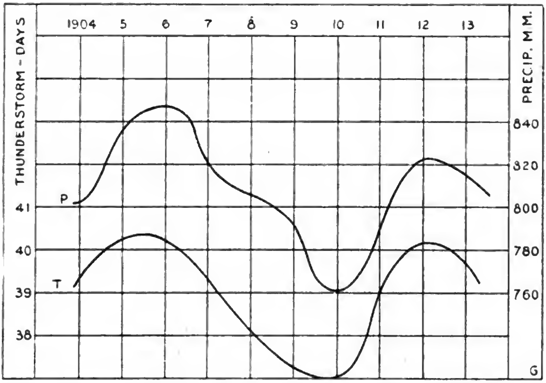
[91] *Meteorologische Zeitschrift*, Braunschweig, 1908, 25th Jhrg., 108.

[92] Otto Steffens, *Ztschr. f. d. gesamte Versicherungswiss.*, Berlin, 1904, 4, pt. 4. (Also Diss.-Berlin, 1904.)

rapid increase suggested by insurance data—has been omitted from the curve and only the fluctuation factor retained.

It will be noticed that the curve of thunderstorm frequency for all Holland closely parallels the curve of thunderstorm injury in all Germany. Hence it seems safe to infer that the frequency of thunderstorm varies pretty much the same way over both countries, and presumably also over many other portions of Europe; that is, roughly as the rainfall varies, or, considering the world as a whole, roughly as the temperature varies.

FIG. 85.



Relation of annual number of thunderstorm days, *T*, to total precipitation, *P*—United States.

Additional statistical evidence of the relation between the annual number of thunderstorm days and the total annual precipitation, kindly furnished by P. C. Day, in charge of the Climatological Division of the Weather Bureau, is shown by Fig. 85, in which the upper line gives, in millimetres, the smoothed annual precipitation of 127 stations scattered over the whole of the United States, and the lower line the smoothed average annual number of thunderstorm days at these same stations. It was thought at first that this relation might differ greatly for those portions of the United States whose climates are radically dissimilar, and for this reason the stations east of the one hundredth meridian provisionally were classed separately from those west of it; but the results for the two sections, being substantially alike, show that for this purpose their division is entirely unnecessary.

As will be seen from the figure, the earliest statistics used are those of 1904. This is because the annual number of such days reported rapidly decreases from 1904 back to about 1890. Indeed, the annual number of thunderstorm days reported per station since 1903 is almost double the annual number per station (practically the same stations) from 1880 to 1890. The transition from the smaller to the larger number was due in great measure, doubtless, to an alteration in station regulations equivalent to changing the official definition of a thunderstorm from "thunder *with* rain" to "thunder *with* or *without* rain." This, however, does not account for the fact that from 1890 to 1904 the average annual number of thunderstorm days reported per station increased, at a nearly constant rate, almost 100 per cent. Either the storms did so increase, which from the fact that there have been no corresponding temperature changes seems incredible, or else there was, on the average, an increase of attention given to this particular phenomenon. At any rate, so continuous and so great an increase in the average number of thunderstorm days cannot be accepted without abundant confirmation, and for this reason the earlier thunderstorm records provisionally have been rejected.

Obviously a much closer relation between the number of thunderstorm days and total precipitation would hold for some months and seasons than for others, but no such sub-grouping of the data has been made, though, presumably, it would give interesting results. The whole purpose of this portion of the study was to arrive at some definite idea in regard to the cyclic change of thunderstorm frequency, to see with what other meteorological phenomena this change is associated, and, if possible, to determine its cause.

Now, it is well known that the average temperature of the world as a whole follows in general the sun-spot changes, in the sense that the greater the number of spots the lower the temperature, and the smaller the number of spots the higher the temperature. This regular relation, however, often is greatly modified[93] by the presence in the high atmosphere of volcanic dust, one invariable effect of which is a lower average temperature. Hence the warm and the cold periods are irregularly cyclic, and also irregular in intensity. Hence, also, the annual amount of precipitation, the frequency of thunderstorms, and many other phenomena must perforce undergo exactly the same irregular cyclic variation.

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[93] Humphreys, W. J., *Bull. Mount Weather Observatory*, Washington, 1913, **6**, 1.

As already stated, the statistical evidence bearing on these conclusions neither is nor can be complete, but the deductions are so obvious and the statistical data already examined so confirmatory that but little doubt can exist of their general accuracy.

Cyclic Ocean Period.—The record of thunderstorms over the ocean is not sufficiently full to justify any conclusions in regard to their cyclic changes. Possibly, as in the yearly and the daily periods, the ocean cyclic period may be just the reverse of that of the land, but this is not certain.

Geographic Distribution.—The geographic distribution of the thunderstorm may safely be inferred from the fact that it is caused by the strong vertical convection of humid air. From the nature of its formation one would assume—and the assumption is supported by observation—that the thunderstorm must be rare beyond either polar circle, especially over Greenland and over the Antarctic continent, rare over great desert regions wherever situated, rare over the trade belts of the oceans, and, on the other hand, increasingly abundant with increase of temperature and humidity, and therefore, in general, most abundant in the more rainy portions of the equatorial regions. The east coast of South America, from Pernambuco to Bahia, is said to be an exception.

An interesting and instructive example of the annual geographic distribution of thunderstorms is given by Fig 86, copied from a statistical study of this subject by W. H. Alexander.[94] Although this example, based on a ten-year (1904–1913) average, refers to only the United States and southern Canada, it nevertheless shows the great influence of humidity, latitude, and topography on thunderstorm frequency.

One of the most striking facts shown by this map is the relatively unusual occurrence of this phenomenon along the Pacific Coast. This exceptional condition is explained by the fact that during the summer time, or season of strong vertical convection, the temperature of the on-shore winds of that region is too low

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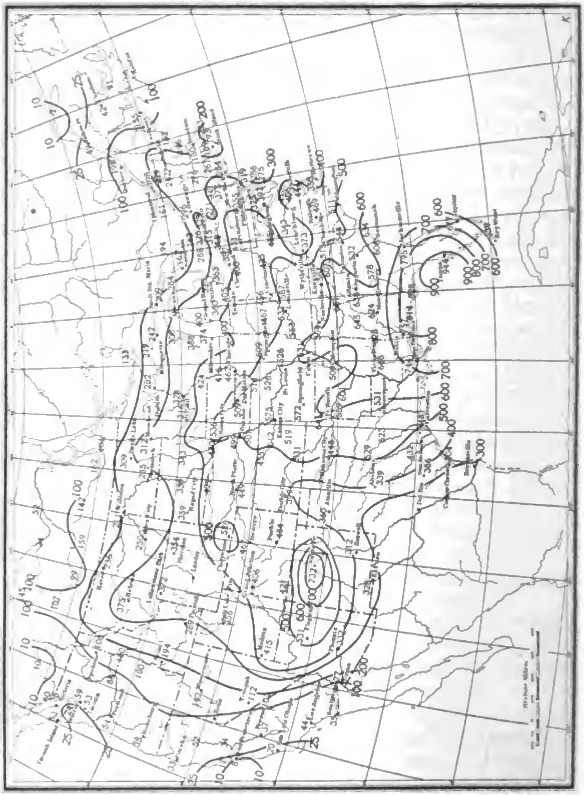
[94] *Monthly Weather Review*, **43**, p. 322, 1915.

FIG. 86.



Total number of thunderstorm days in the United States during the ten years, 1904–1913, inclusive. (Alexander.)

and their humidity too small to permit of the ready formation over the heated interior of abundant cumuli, without which, as already explained, thunderstorms do not occur.

Pressure and Temperature Distribution.—In illustrating the occurrence of thunderstorms with reference to the disposition of isobars and isotherms, or the distribution of atmospheric pressure and temperature, typical weather maps of the United States,[95] Figs. 87 to 101, have been used, not because the thunderstorms of this country are different in any essential particular from those of other countries, but chiefly as a matter of convenience in making the drawings. To facilitate their study, each of the several types discussed is illustrated with three consecutive maps. The first shows the 12-hour antecedent conditions, the second the particular pressure-temperature distribution in question, and the third the 12-hour subsequent conditions.

In these figures the isobars, in corrected inches of mercury as read on the barometer and reduced to sea-level, and the isotherms in Fahrenheit degrees, are marked by full and dotted lines respectively. The legend " LOW " is written over a region from which, for some distance in every horizontal direction, the pressure increases. Similarly, the legend " HIGH " applies to a region from which, in every horizontal direction, the pressure decreases. The arrows, as is customary on such maps, fly with the wind, while the state of weather is indicated by the usual U. S. Weather Bureau symbols.

Obviously, the key to the geographic distribution of thunderstorms—that is, the distribution of conditions likely to induce strong vertical convection of humid air—is also the key to their probable location with reference to any given system of isotherms and isobars, or distribution of atmospheric temperature and pressure. From this standpoint the places of their most frequent occurrence are:

a. Regions of high temperature and widely extended nearly uniform pressure (see Figs. 87, 88, and 89).

The conditions are still more favorable to the genesis of thunderstorms when the air is humid and the pressure, partly

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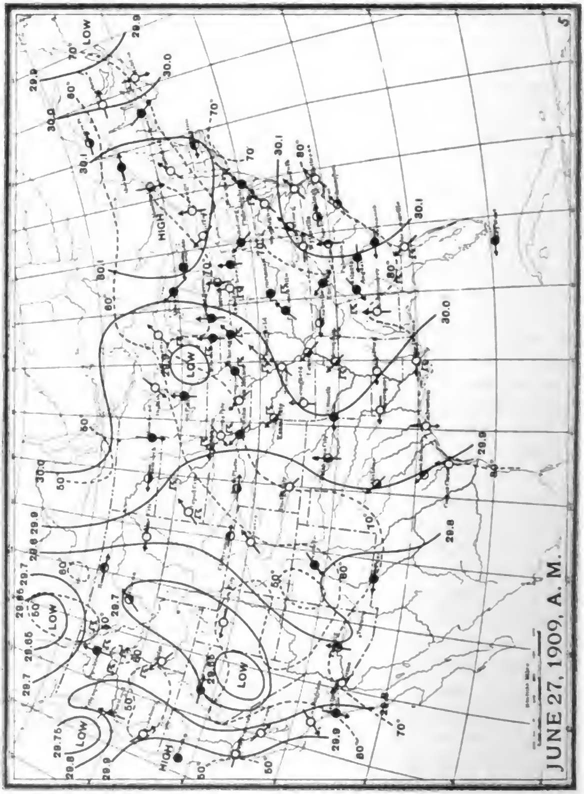
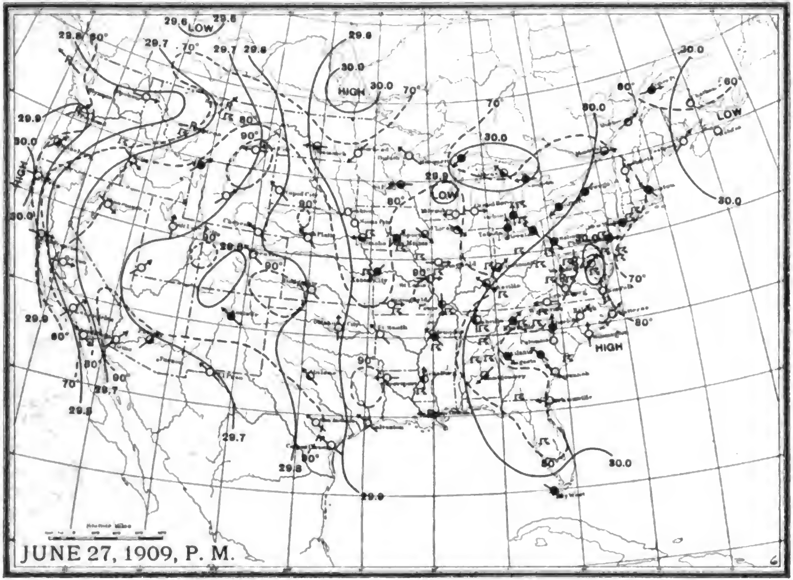
[95] The author wishes to acknowledge the kind coöperation of the official forecasters of the U. S. Weather Bureau in selecting maps typical of thunderstorm conditions in the United States.

Fig. 87.



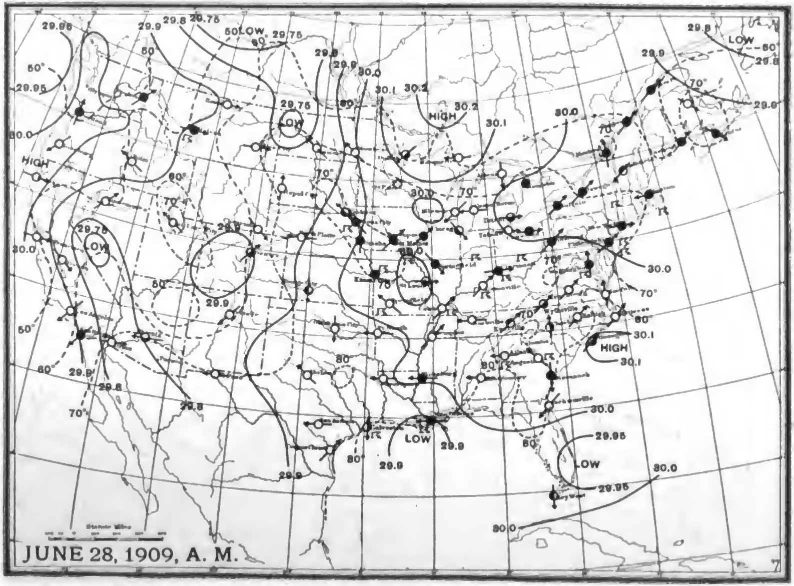
Weather map, 8 A.M., June 27, 1909, typical conditions at beginning of "heat" thunderstorms: ○, clear; ◐, partly cloudy; ●, cloudy; R, rain; K, thunderstorm.

FIG. 88.



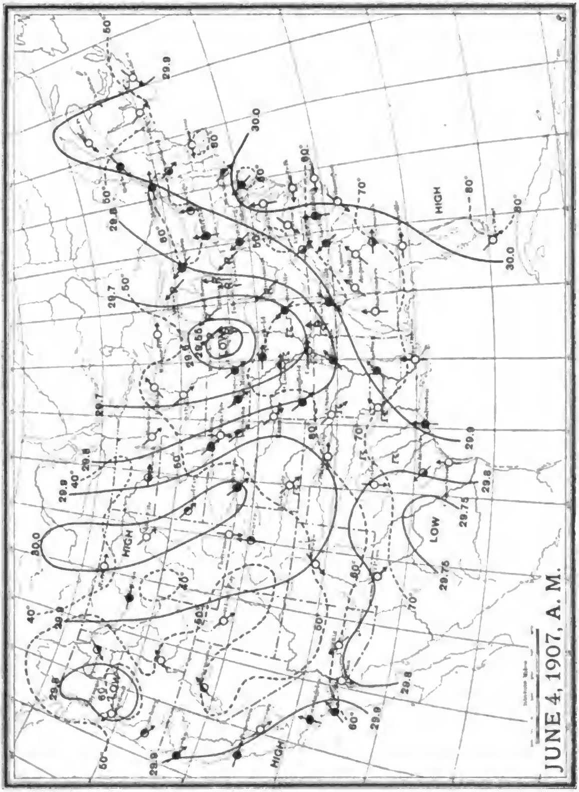
Weather map, 8 P.M., June 27, 1909, typical of "heat" thunderstorms: ○, clear; ◐, partly cloudy; ●, cloudy; R, rain; ⚡, thunderstorm.

FIG. 89.



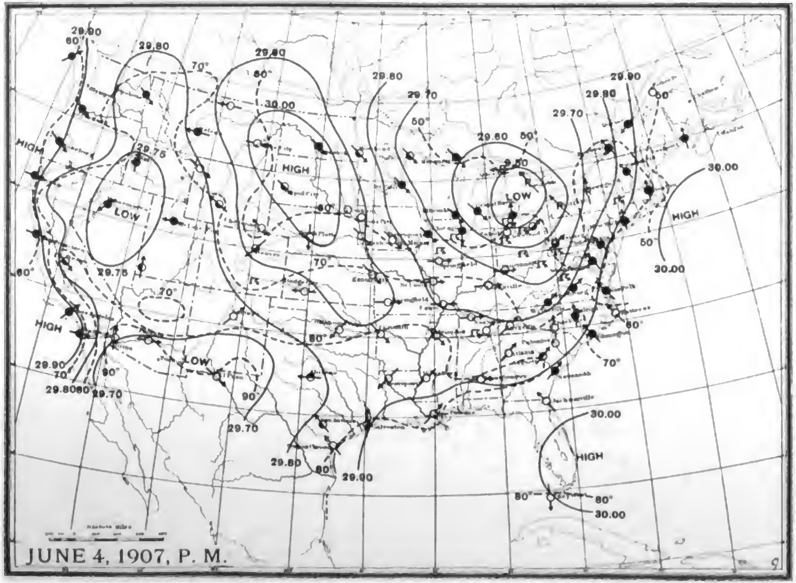
Weather map, 8 A.M., June 28, 1909, typical of conditions at decline of "heat" thunderstorms: O, clear; ◐, partly cloudy; ●, cloudy; R, rain; K, thunderstorm.

FIG. 90.



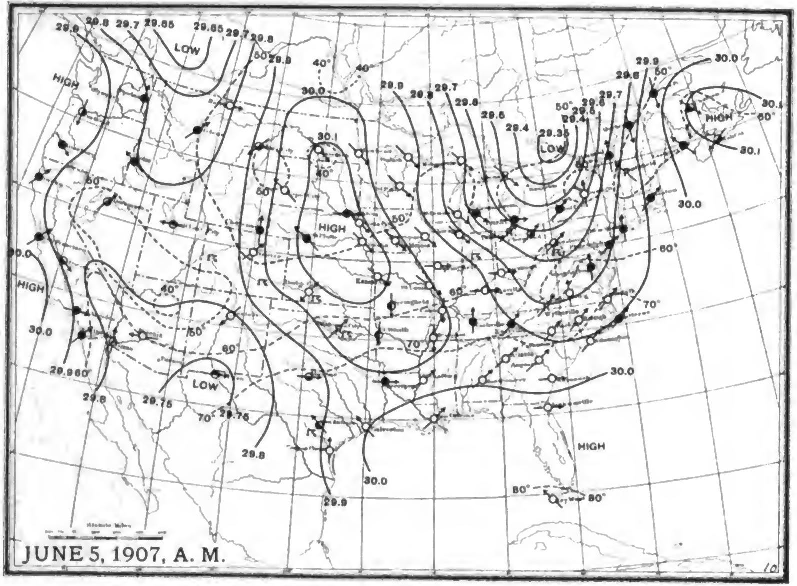
Weather map, 8 A.M., June 4, 1907, typical of conditions at beginning of "cyclonic" thunderstorms: O, clear; ◗, partly cloudy; ●, cloudy; R, rain; Ʀ, thunderstorm.

FIG. 91.



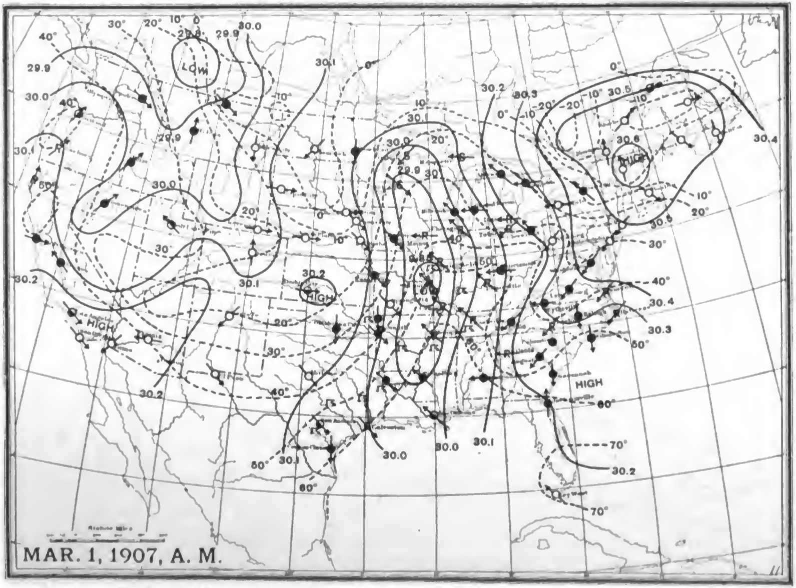
Weathermap, 8 P.M., June 4, 1907, typical of "cyclonic" thunderstorms: ○, clear; ◗, partly cloudy; ●, cloudy; R, rain; Ꞧ, thunderstorm.

FIG. 92.



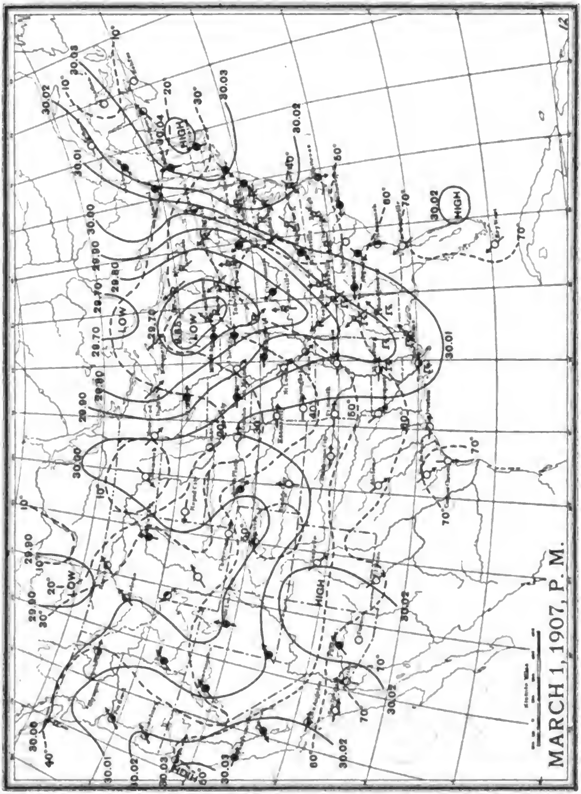
Weather map, 8 A.M., June 5, 1907, typical of conditions at decline of "cyclonic" thunderstorms: ○ clear; ◗, partly cloudy; ●, cloudy; R, rain; R̅, thunderstorm.

FIG. 93.



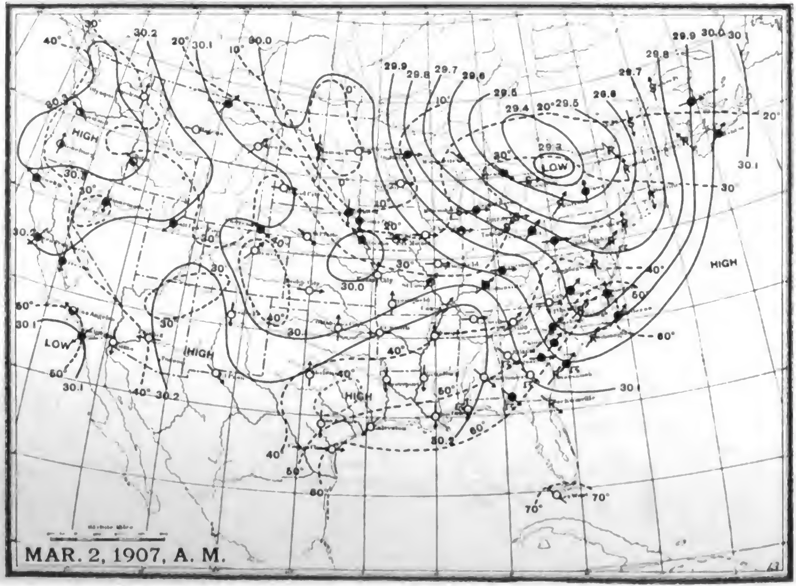
Weather map, 8 A.M., March 1, 1907, typical of conditions at beginning of "tornadic" thunderstorms: ○, clear; ◐, partly cloudy; ●, cloudy; R, rain; Ꝁ, thunderstorm.

FIG. 94.



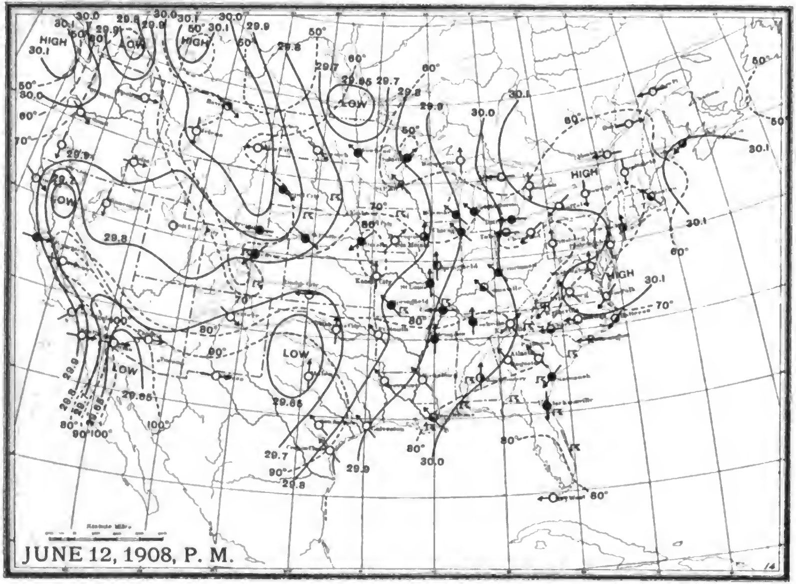
Weather map, 8 P.M., March 1, 1907, typical of "tornadic" thunderstorms: ○, clear; ◐, partly cloudy; ●, cloudy; R, rain; ꓘ, thunderstorm.

FIG. 95.



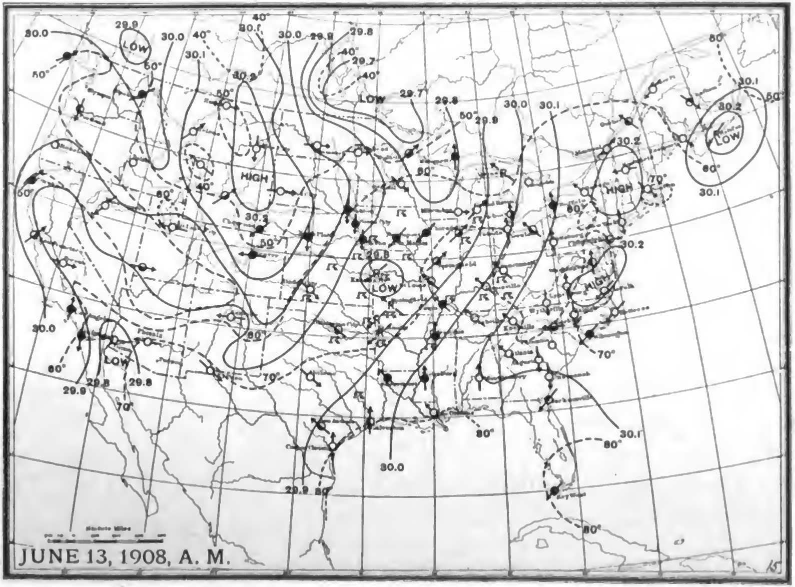
Weather map, 8 A.M., March 2, 1907, typical of conditions at decline of "tornadic" thunderstorms: ○, clear; ◐, partly cloudy; ●, cloudy, R, rain, R̄, thunderstorm.

FIG. 96.



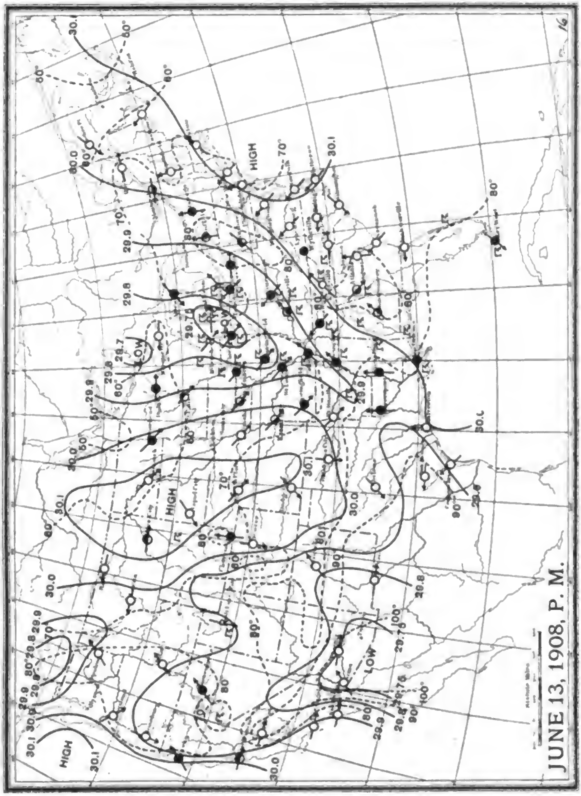
Weather map, 8 P.M., June 12, 1908, typical of conditions at beginning of "trough" thunderstorms: ○, clear; ◐, partly cloudy; ●, cloudy; R, rain; R̄, thunderstorm.

FIG. 97.



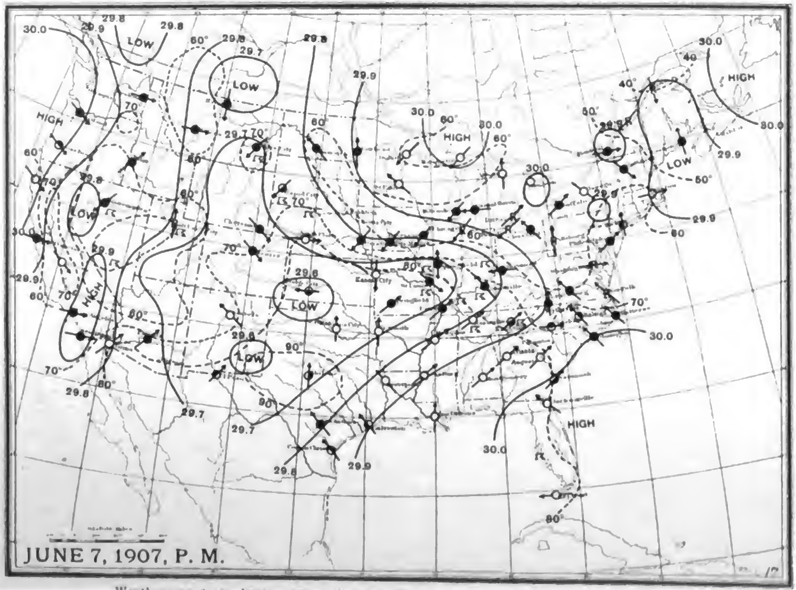
Weather map, 8 A.M., June 13, 1908, typical of "trough" thunderstorms: ○ clear; ◐, partly cloudy; ●, cloudy; R rain; Ʀ, thunderstorm.

FIG. 98.



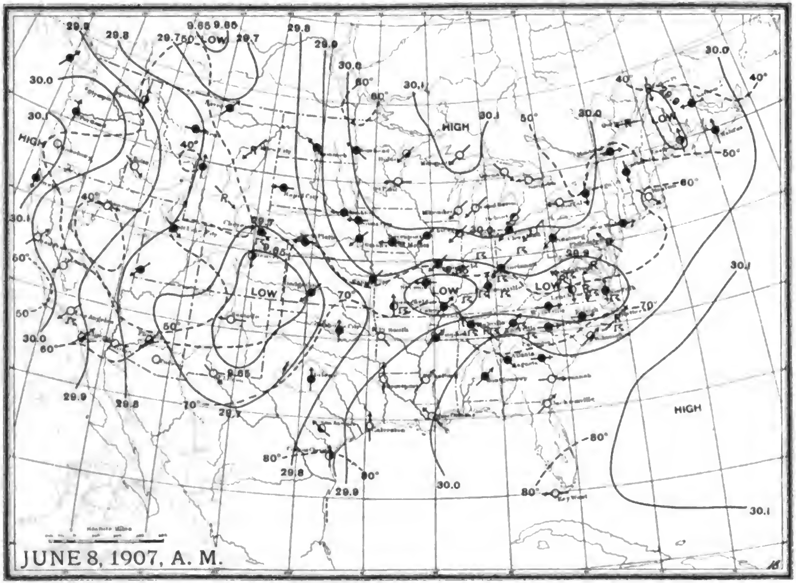
Weather map, 8 P.M., June 13, 1908, typical of conditions at decline of "trough" thunderstorms: O, clear; ◐, partly cloudy; ●, cloudy; R, rain; R̄, thunderstorm.

FIG. 99.



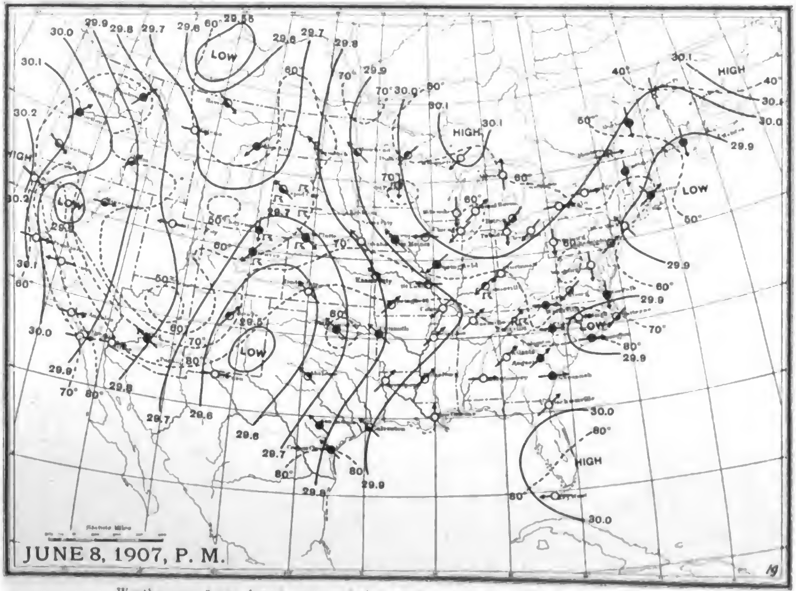
Weather map, 8 P.M., June 7, 1907, typical of conditions at beginning of "border" thunderstorms: ○, clear; ◐, partly cloudy; ●, cloudy; R, rain; Ʀ, thunderstorm.

FIG. 100.



Weather map, 8 A.M., June 8, 1907, typical of "border" thunderstorms: ○, clear; ◐, partly cloudy; ●, cloudy; R, rain; R̄, thunderstorm.

FIG. 101.



Weather map, 8 P.M., June 8, 1907, typical of conditions at decline of "border" thunderstorms; ○, clear; ◐, partly cloudy; ●, cloudy; R, rain; Ʀ, thunderstorm.

because of the humidity, slightly below normal or, at most, but little above normal.

When the pressure is approximately uniform the winds are light, and therefore the turbulence and general mixing of the lower air practically negligible, hence every opportunity is given for the surface air to become strongly heated and thereby, finally, to establish vigorous local convections, with their consequent thunderstorms. Such storms, always favored by the drafts up the sides of mountain ranges, and particularly by those up steep mountain peaks and strongly heated valleys, are, of course, most frequent of summer afternoons, and are especially liable to occur at the end of two or three days of unusually warm weather, when the lower air has become so heated that convection extends to relatively great altitudes. They develop here and there sporadically, hence the name "*local*" thunderstorms; last, as a rule, only an hour or two, and travel but a short distance—those that form over mountain peaks often do not travel at all. They also frequently are referred to as "*heat*" thunderstorms, from the fact that, under the given conditions, the necessary initial convection is essentially, if not wholly, due to surface heating.

Local or heat thunderstorms seldom are especially violent and dangerous, and fortunately so, since they are exceedingly numerous, constituting, as they do, well-nigh the only type of thunderstorm in the tropics, and also, perhaps, the most common type in the warmer portions of the temperate zones.

b. The southeast quadrant (northeast, in the Southern Hemisphere), or less frequently, the southwest (northwest, in the Southern Hemisphere), of a regularly formed low, or typical cyclonic storm (see Figs. 90, 91, and 92).

In this case, the temperature gradient essential to a rapid vertical convection is not produced chiefly by surface heating, as it is during the genesis of "*heat*" thunderstorms, but, in great measure, results from the more or less crossed directions of the under- and over-currents of air, the under being directed spirally inward toward the region of lowest pressure and the over tending to follow the isobars. The surface air of the quadrant in question, therefore, normally flows from lower and warmer latitudes, while with increasing altitude the winds come more and more nearly from the west, or even northwest. This crossing of the air currents, then, the lower coming from warmer sections and the upper from regions not so much warmer—possibly even colder—progressively increases the vertical temperature gradient, or rate of temperature decrease with increase of altitude, and therefore may frequently be, doubtless often finally is, the determining cause of rapid vertical convection and the formation of a thunderstorm.

This particular type of thunderstorm, commonly known as the "*cyclonic*" thunderstorm, is almost wholly confined to the temperate and higher zones, for the simple reason that tropical cyclones, themselves of infrequent occurrence, seldom can have the necessary temperature contrast between its winds of different directions, since all come from equally warm regions. Nevertheless, thunderstorms do occur in connection with many, perhaps nearly all, tropical cyclones. They occur, however, either incidentally during the development of such disturbances or else, later, along their borders and not, or but rarely, within the body of strong winds, and belong, therefore, to the "*heat*" variety rather than to the "*cyclonic.*"

c. The barometric valley between the branches of a distorted or V-shaped cyclonic isobar (see Figs. 93, 94, and 95).

This region is also favorable to the formation of secondary lows, which, though often of small area, sometimes are very intense, even to the genesis of the tornado, the severest of all storms.

Just how specific examples of this type of pressure distribution originated may not always be clear, but, however established, such distribution necessarily leads to opposing surface winds, since these always blow inward at an angle to the isobars, and also to more or less oppositely directed neighboring upper currents, a kilometre or more above the surface, where they tend rather closely to follow the isobars. The winds of each level, the lower and the upper, tend to produce independent effects. Thus the opposing or conflicting surface winds cause such an irregular mixing of the air and such over- and under-running of currents as is likely to establish, here and there, a convection of thunderstorm magnitude. Hence, presumably, the frequency of thunderstorms along the valleys of low-pressure basins. On the other hand, the oppositely directed adjacent, not conflicting, but swift upper currents, on being deflected or drawn together by the convection of the rising current, have their radii of curvature so changed as mechanically to produce, in the middle atmosphere, violent vortices of limited cross-section, in conformity with the well-known law of the conservation of areas: that is, in conformity with the fact that the angular velocity, or rate of spin, varies inversely with the square of the radius of curvature. The more violent of these vertical atmospheric whirls, accompanied by thunder and rain and often extending down to the surface of the earth, where they become destructive, are known as tornadoes. Hence thunderstorms generated in the barometric region under discussion, the region in which tornadoes most frequently originate and develop, might properly be called "*tornadic*" thunderstorms.

Atmospheric conflicts and turmoil of the nature just described obviously may occur at any place along the protrusion, or valley, of the low-pressure basin, and therefore often do occur, even simultaneously, here and there, along its entire length, and together form the well-known "line squall." Besides, as the whole cyclonic condition moves forward in general from west to east, maintaining, in a measure, for many hours its identity of form and nature, it follows that its valley of low pressure, and therefore its line of thunderstorms, must also travel with it in the same general direction and with approximately the same velocity.

A line or row of thunderstorms—a "line squall"—as observations show, always moves across its own axis, not necessarily at right angles, but nevertheless across and not parallel to it, nor even approximately so. The chief reason for this is not the axial direction of the low-pressure valley, which, indeed, though usually running south, may have any orientation from the parent basin, but rather the fact that the valley itself, together with its accompanying thunderstorm conditions, travels across and not along its own direction.

In this connection it is also worth noting that the temperature distribution in the wake of a thunderstorm renders the occurrence of an immediate successor improbable, as will be explained later. Hence, while a considerable number of thunderstorms may and often do travel abreast, they can never follow each other closely in file.

d. The region covered by a low-pressure trough between adjacent high-pressure areas (Figs. 96, 97, and 98).

Along the adjacent borders of two neighboring anticyclones—that is, along the barometric trough between them—the surface winds from one side are more or less directly opposed to those of the other, each being directed spirally out from the region of higher pressure. Hence, because of the overrunning, as explained under *c*, and the resulting temperature gradients, this also is a region of frequent thunderstorms. Here, too, a number of more or less independent storms may exist simultaneously along the same line, and advance abreast for considerable distances across the country.

There does not appear to be any independent or distinctive name for the thunderstorm generated under this type of pressure distribution. Perhaps it might, with some justification, be called the "*anticyclonic*" thunderstorm, or even the "trough" storm.

e. The boundary between warm and cold waves (see Figs. 99, 100, and 101).

Along such a boundary the direction of flow of the warm, humid layers of air is more or less opposite, as shown on the maps, to that of the colder ones. Therefore it must frequently happen that at irregular intervals along such a boundary upper air coming from the cold area overruns a section of surface air belonging to the warm region. Now, wherever this overrunning on the part of the cold air does occur the vertical temperature gradient is likely to be abruptly and greatly increased, and wherever, as a result of either the initial overflow or of further movement, the new gradient exceeds the adiabatic rate of temperature change, as, analogous to case *b*, it often must, under the given conditions, vertical convection, with rain, thunder, and lightning, is apt to occur. Hence, as stated, the boundary between warm and cold waves is another place favorable to the genesis of the thunderstorm. Here, too, as in cases *c* and *d* above, a characteristic name is lacking. Possibly with reference to its place of occurrence—that is, along the boundary between warm and cold waves—one might call it the "border" storm.

The above five types of weather conditions, together with their innumerable variations and combinations, probably include all that are distinctly favorable to the development of thunderstorms. Each tends to establish an adiabatic, or even superadiabatic, temperature gradient up to the cloud level, the one thing essential to the production of strong vertical convection, the progenitor, as we have seen, of the thunderstorm.

(*To be continued.*)

PERMANENCE IN PHOTOGRAPHIC PRINTS.

BY

HENRY LEFFMANN,

Member of the Institute.

IN the current number of the JOURNAL of the Institute (May, 1918) a short abstract is given from the *British Journal of Photography*, concerning methods of producing permanent photographic prints. The matter is of great importance, nowadays, because the application of photography to the copying of written and printed records is rapidly displacing the old method of transcription. The general features of the method were presented by me in a paper read before the Photographic Section of the Institute in October, 1901, and published in the JOURNAL a month later. I there showed the great advantage that would accrue if the ordinary municipal records, such as deeds, mortgages, and wills, were copied by photography instead of the present tedious and fallible methods of transcription. Not the least advantage of the photographic method is that the signatures, erasures, corrections, spelling, and punctuation are faithfully reproduced.

The *British Journal* article speaks of a guarantee of permanency for about a quarter of a century, but this is far short of what official business will require. The processes mentioned are platinum, carbon and silver bromide. Under existing conditions, platinum should not be allowed for use in photography. The carbon print is unfading, whether produced in the earlier forms or by the later and now much used "gum-bichromate" method. It is notable that the *British Journal* does not refer to the blue-print. This seems to be as permanent as any. It is inexpensive, simple in manipulation, and reproduces distinctly the finest detail. When I prepared the paper noted above, I inquired of a railroad engineer as to the durability of blue-prints, and he told me that his company had in its vaults prints at least twenty-five years old, which, so far as could be judged by inspection, were as vivid as the day they were made. I think, therefore, that in this matter the blue-print should be given a full investigation.

A very important feature of this question is the quality of the paper. It is likely that more failures in permanency will obtain from bad paper than from a bad process. Methods of testing paper are now so highly developed that it will be quite easy to establish specifications which will give a paper at reasonable price that will last for centuries. It should be free from chemicals that may react with the deposit that forms the print.

It is greatly to be regretted that the record offices of our municipal, state and national governments have not adopted extensively the photographic methods of copying. Such methods are more rapid and cheaper than the transcription, even when typewriting machines are employed, while of course as far as regards accuracy, even to the minutest detail, the best transcription cannot compare with the photograph.

Proposed Ramsay Memorial Fund. C. BASKERVILLE. (Communication, The College of the City of New York.)—After the death of Sir William Ramsay, in July, 1916, a memorial meeting was held in London to commemorate his thirty-five years of service in physical and chemical sciences, education, and public welfare. This gathering of distinguished men, under the chairmanship of Lord Rayleigh, decided to raise a substantial fund as a memorial to be used in the establishment of Ramsay Research Fellowships, tenable wherever necessary facilities might be available, and a Ramsay Memorial Laboratory of Engineering Chemistry at the University of London, where he served twenty-six of his most fruitful years of activity.

A committee of men, prominent in the physical and chemical sciences in Great Britain, including the leaders of the Coalition Government and Ambassadors then accredited to the Court of St. James, was later organized. Through this general organization committees were appointed and correspondence to that end carried on throughout the civilized world. The sum set out to be raised was £100,000. To date something over £300 have already been contributed by residents of the United States. The committee expects some generous contributions, but it hopes especially to have a great number of small subscribers. The receipt of contributions for one dollar or over, sent to the Ramsay Memorial Fund Association, 50 East Forty-first Street, New York City, will be promptly acknowledged.

A more suitable memorial of the epoch-making work of this noted investigator could scarcely be devised. By such a foundation a real and, at this time, thoroughly appreciated need will be served.

NOTES FROM THE U. S. BUREAU OF STANDARDS.*

COMPARATIVE TESTS OF CHEMICAL GLASSWARE.[1]

By Percy H. Walker and F. W. Smither.

[ABSTRACT.]

BEAKERS of Kavalier glass, and beakers and flasks of Macbeth Evans Glass Co., Pyrex, Jena, Nonsol, Fry and Libbey glasses were tested for chemical composition, coefficient of expansion, refractive index, strain, behavior on repeated evaporation, resistance to heat and mechanical shock, and to solution in a variety of chemical reagents.

No conclusions as to the relative values of the different wares can be drawn from the chemical analyses, though these analyses may be useful by enabling the chemist to choose a glass which will yield no objectionable ingredient to the solutions used in any particular piece of work. The coefficient of expansion of all the glasses is low and is unusually so in Pyrex ware. All the ware shows more or less strain, but it was disappointing to find that no information as to liability to break under sudden changes in temperature or mechanical shock could be obtained by an examination for strain. All the ware tested showed good resistance to repeated evaporation of a salt solution. While the heat and mechanical shock tests were performed on too small a number of pieces to justify positive conclusions, they indicated that the Kavalier and M. E. G. Co. ware are less resistant than Jena, Nonsol, and Fry wares, the Libbey somewhat more resistant and the Pyrex ware distinctly more resistant. The Kavalier ware is unsatisfactory as regards solubility in water; all the other wares appear satisfactory in this respect. All the ware is resistant to acids, Kavalier is least resistant to carbonated alkalies, Pyrex more resistant than Kavalier but less resistant than the others. Kavalier and M. E. G. Co. wares are more resistant to boiling caustic alkaline solutions than the others but the differences are not great. All the glasses are much attacked by evaporating caustic alkalies. Ammonia water has about the same effect as mixtures of ammonium chloride and sulphide. The authors are of the opinion that considering all the tests each of the American wares is superior to the Kavalier and equal or superior to the Jena ware.

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* Communicated by the Director.

[1] Technologic Papers of the Bureau of Standards, No. 107.

Antifreezing Solutions for Automobile Radiators. ANON. (U. S. Bureau of Standards, Department of Commerce, Washington, D. C., March 20, 1918.)—The ideal antifreezing compound is one that will prevent freezing of the radiator liquid without injuring either engine or radiator, that will not lose its non-freezing properties after continued use, and that does not materially change the boiling-point of water when dissolved in it. There are two general types of these compounds; one a solution in water of alcohol or glycerin, or a mixture of the latter two; the other, a solution in water of calcium chloride or the dry salt itself, which contains sometimes small amounts of other substances, such as salt, sal ammoniac, sugar, or syrup. Kerosene and similar oils, without admixture, are sometimes used.

Kerosene has a lower freezing-point and higher boiling-point than water, but the inflammability of its vapor makes it dangerous to use, and its high and uncertain boiling-point might lead to the serious overheating of the engine, or even to the melting of the solder in the radiator. Its marked solvent action on rubber parts is also an objection to its use. The alcohol-water type is the most common and is not generally sold under any trade name, but recently there have appeared on the market a number of antifreezing compounds of the calcium chloride type. These compounds are sold under a variety of names, and startling claims are made for their effectiveness and lack of injurious effects.

The alcohol solutions do not exert a greater corrosive action than water alone. This can be predicted from theoretical considerations and is well established in practice. However, wood alcohol sometimes contains free acid, such as acetic acid, which is objectionable, and for that reason wood alcohol should be used only when it is known to be free from acids. The calcium chloride compounds exert a greater corrosive action than water on the engine jacket, on the solder in the radiator, and on aluminum, which is sometimes used in manifolds, pumps, and headers. Another troublesome effect of calcium chloride solutions is experienced if small leaks occur in the radiator, the water jackets, or connections, and the solution comes in contact with the spark-plugs and ignition wires. In some cases the drops of the solution may be carried back on the engine in a more or less atomized state, assisted by the fan when running. The salt deposited when the water evaporates is very difficult to remove, and when it cools absorbs water and becomes a good electrical conductor, short-circuiting the spark-plugs and sometimes making it impossible to start the engine. The difficulty may disappear when the engine is heated up. There are also certain conditions in the manufacture of calcium chloride which may result in a compound that will deposit large crystals in the radiator as the solution cools; this may prevent effective circulation.

NOTES FROM NELA RESEARCH LABORATORY.*

THE VISIBILITY OF RADIATION.

By Edward P. Hyde, W. E. Forsythe and F. E. Cady.

In connection with an investigation of the brightness of a black body at various temperatures, it was desired to check the observations against values derived by computation, using the Planck energy equation and visibility data. As the only recent experiments on the latter have all been made by the use of the flicker photometer and as there is evidence that results by this method are at variance with those obtained by the method of direct comparison ordinarily used in photometry, possibly because of inherent differences and possibly due to conditions imposed in the flicker method such as restricted field size, it seemed desirable to obtain new data on the visibility function by the direct comparison method under conditions comparable with those obtaining in the black-body brightness determinations referred to above.

The distinguishing characteristics of the investigation, apart from the employment of the direct-comparison principle and from the conditions with respect to field size, etc., used in ordinary photometric practice, are the use of the step-by-step method and the determination of the energy distribution in the spectrum. The steps chosen were so small ($0.0052\ \mu$ in the red to $0.0022\ \mu$ in the blue) that the hue difference while appreciable, did not cause any decided difficulties in making the settings. The energy was evaluated by determining the color temperature of the source, and computing the distribution by means of Planck's equation, allowing for dispersion and absorption by the optical system, and for scattered light. In this way the relative energy entering the eye in the different parts of the spectrum was readily determined.

The apparatus employed consisted in an ordinary Lummer and Brodhun spectrophotometer provided with a special slit which could be moved a definite fixed amount, 0.15 mm., in order to provide the means for the shift of one spectrum with respect to the other, this procedure being required to carry out the step-by-step method. As a source a flat filament tungsten lamp was used, operating at a color temperature approximately 2045° K. Measurements were made by 29 observers and the 29 luminosity curves obtained, after reducing them to the same area, were averaged at each wave-length. The results are given in Column 2 of Table I. The relative average visibility data were reduced on the basis of equal areas of the luminosity curves for the chosen color temperature (approximately 2045° K.). The results of other recent investigators are also included.

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* Communicated by the Director.

TABLE I.

Data on Relative Visibility.

Wave-Length.	Hyde Forsythe Cady.	Ives Kingsbury.	Nutting.	Coblentz Emerson.	Reeves.
0.50μ	0.328	0.318	* 0.314	0.316	0.275
.51	.515	.473	.456	.503	.474
.52	.698	.637	.646	.710	.686
.53	.847	.801	.815	.862	.841
.54	.968	.915	.925	.954	.935
.55	.996	.988	.986	.994	.993
.56	.995	.996	.995	.998	.985
.57	.944	.947	.949	.968	935
.58	.855	.859	.871	.898	.836
.59	.735	.758	.762	.800	.710
.60	.600	.653	.634	.687	.580
.61	.464	.534	.498	.557	.446
.62	.341	.396	.368	.427	.319
.63	.238	.283	.268	.302	.214
.64	.154	.183	.166	.194	.140
.65	.095	.110	.105	.115	
.66	.052	.068	.058	.064,	

*Revised values kindly furnished by Doctor Nutting.

In addition to the investigation just described a supplementary investigation of the relative visibility was made, using the same spectral pyrometer and method as previously used for studying this function in the red and blue ends of the spectrum.[1] Ten out of the twenty-nine observers participated, and the results form a curve somewhat flatter near the centre and dropping off more rapidly towards the two ends of the spectrum. The previously obtained data in the red and blue ends of the spectrum fit nicely on the ends of this curve. In Table II are given data recommended by the authors on relative visibility covering practically the entire visible spectrum. The values from 0.50 μ to 0.64 μ are those given in Column 2 of Table I. For the red end are chosen the previously published data of Hyde and Forsythe brought into agreement with the central region of the curve at 0.64 μ. For the blue end the published data of Hartman have been chosen as the best.

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[1] *Astrophys. Jour.*, **42**, p. 285, 1915.
Phys. Rev. (2) **11**, p. 327, 1918.

TABLE II.

Relative Visibility Data for Entire Spectrum.

Wave-Length.	Relative Visibility.	Wave Length.	Relative Visibility.	Wave-Length.	Relative Visibility.
0.40μ	0.00009	0.52μ	0.698	0.64μ	0.154
.41	$.0006_2$	.53	.847	.65	.094
.42	$.004_1$	.54	.968	.66	.051
.43	$.011_5$	.55	.996	.67	.026
.44	.022	.56	.995	.68	$.012_5$
.45	.036	.57	.944	.69	$.006_2$
.46	.055	.58	.855	.70	$.003_1$
.47	.087	.59	.735	.71	$.001_5$
.48	.138	.60	.600	.72	$.0007_4$
.49	.216	.61	.464	.73	$.0003_6$
.50	.328	.62	.341	.74	$.0001_8$
.51	.515	.63	.238	.75	.00009
				.76	.00005

NELA RESEARCH LABORATORY,
National Lamp Works of General Electric Company,
Nela Park, Cleveland, Ohio, May, 1918.

The Action of Bleaching Agents in Fibres. J. M. MATTHEWS. (*Color Trade Journal,* through *Paper,* vol. 21, p. 13, November 28, 1917).—Bleaching in its general sense may be considered as a decoloration, or, more properly speaking, a destruction of the natural coloring matter which may be present in the substance under treatment. This is in contradistinction to the term "stripping," which is used in cases where the color from a dyed material is removed. All of the textile fibres, whether of animal or vegetable origin, possess more or less coloring matter or pigment in their composition. Wool, for instance, with its congener hair is known to exist in a number of colors, varying from a pale yellow to a deep brown or black. Even ordinary "white" wool has a slightly yellowish cast on scouring-out, due to the presence of a natural organic pigment in the fibre. In the large majority of cases the presence of natural coloring matter in the fibre is not appreciably detrimental to the color to be produced by the dyestuffs. When delicate shades and tints, however, are desired, or when it is required that the fibre be left undyed in a white condition, it generally becomes necessary to remove the natural coloring matter from the fibre by some suitable chemical treatment. The process by which this is accomplished is termed "bleaching," a word signifying "to whiten."

The destruction or removal of the natural coloring matter in the textile fibres may be brought about by a variety of methods. In certain cases it is only necessary to tint the material with a complementary color to that already present, and, as this latter is usually a yellowish or a yellowish-brown tint, the complementary tint combines with the natural color, producing a neutral gray tone. As the eye is far less sensitive to this character of tint than it is to either of the complementary or component tints, the material appears, in consequence, to have much less color, or, in other words, appears whiter. In this tinting method of bleaching there is no actual destruction of the natural coloring matter present, and there is in reality more color in the fibre after tinting than before, only it is not so apparent to the eye. A very familiar example of this method of bleaching or whitening is the so-called "bluing" in the ordinary home wash or in the laundry.

The coloring matters existing in the raw textile fibres are of organic nature; that is to say, they are of animal or vegetable origin, not mineral compounds. Being of this nature, they are peculiarly susceptible to the action of various chemical agents, both of a reducing and oxidizing character.

It is on these facts that the two processes of bleaching at present in vogue depend for their efficiency. The one which is used almost exclusively in connection with the animal fibres involves the use of a strong reducing agent, such as sulphurous acid, sodium hydrosulphite, etc. The other process employs a strong oxidizing agent, such as hydrochlorous acid (or its salts), which finds its use in connection with the vegetable fibres, or hydrogen peroxide, which may be employed in connection with all fibres.

Other processes of bleaching have been introduced from time to time, some of which depend upon the electric current, like the so-called electrolytic method. This method is carried out by means of a solution of sodium hypochlorite, a current of electricity being passed through a solution of common salt (sodium chloride) whereby sodium hypochlorite is formed, and this serves as the bleaching agent. The hypochlorite is also prepared from liquid chlorine by dissolving the gas in a suitable alkali, such as a solution of soda ash or caustic soda. A more direct use of electricity has been suggested as a means of rendering chlorine gas (in the presence of moisture) more effective in its bleaching qualities; the gas being conducted through an apparatus provided with two electrodes between which electric sparks are continually passing. Ozone has also been employed as an oxidizing bleaching agent, but the high cost of its production makes it almost prohibitive for general use.

THE FRANKLIN INSTITUTE.

(*Proceedings of the Stated Meeting held Wednesday, May* 15, 1918.)

Hall of The Franklin Institute,
Philadelphia, May 15, 1918.

President Dr. Walton Clark *in the Chair.*

Additions to membership since last report, 1.

The Chairman announced that the business of the meeting would be the annual presentation of the Franklin Medal, the Institute's highest award, in recognition of distinguished scientific and technical achievements, and called upon Dr. Harry F. Keller, who gave an account of the work of Signor Guglielmo Marconi, of Bologna, Italy, recently recommended by the Institute's Committee on Science and the Arts for the Franklin Medal in recognition of "His brilliant inception and successful development of the application of magneto-electric waves to the transmission of signals and telegrams without the use of metallic conductors."

Doctor Keller then presented His Excellency, Count V. Macchi de Cellere, Ambassador of the Royal Italian Government to the United States, who received the medal for Signor Marconi, and conveyed the thanks of his Government and of the recipient for the honor conferred upon him.

Doctor Keller then introduced Thomas Corwin Mendenhall, Sc. D., LL.D., of Ravenna, Ohio, who had also been recommended for the award of the Franklin Medal in recognition of "His fruitful and indefatigable labors in physical research, particularly his contributions to our knowledge of physical constants and electrical standards."

The Chairman presented the medal to Doctor Mendenhall, who expressed his thanks for the honor conferred upon him, and then read his paper, "Some Metrological Memories." He outlined the progress made in electricity during the last fifty years. Reference was also made to the International Electrical Exhibition of 1884, held under the auspices of The Franklin Institute, and the work accomplished by the International Electrical Conference held in Philadelphia in the same year. An account was given of the efforts to establish a system of electrical units, the adoption of the definitions for the principal practical units by the International Electrical Congress of 1893, and the legalization of these by Congress. The speaker expressed the opinion that metrology is the mother of science and of art, certainly of all the exact sciences and of nearly all of the arts, and that without it there could be no astronomy, no physics, no chemistry, no engineering, no architecture.

At the close of the address the thanks of the meeting were extended to the guests.

Adjourned.

George A. Hoadley,
Acting Secretary.

(A full account of the meeting will appear in the next issue.)

MEMBERS OF THE FRANKLIN INSTITUTE WHO ARE IN THE ACTIVE MILITARY OR NAVAL SERVICE OF THE UNITED STATES GOVERNMENT.

Name and rank	Branch of service	Location
Abbott, A. C., Lieut.-Col.	Greenleaf School of Military Hygiene	Chickamauga Park, Ga.
Allen, Henry B., 1st Lieut.	Ordnance Dept., U. S. R.	France
Anderson, Geo. L., Colonel	Board of Ordnance & Fortification	Washington
Atherholt, Gordon Meade	Aeronautical Mechanical Engineer, Signal Corps	Washington
Atterbury, W. W., Brig. Gen.	Director-General of Railways	France
Bacon, Raymond Foss, Lt. Col.	Head of Chemical Service Section, U.S.N.A.	France
Barnhart, G. Edw.	Aeronautical Mechanical Engineer, Signal Corps	Fairfield, Ohio
Barr, John H., Major	Ordnance Reserve Corps	Washington
Barrett, C. D., Major	9th Engineers	
Bartow, Edward, Major	U.S.N.A. Sanitary Corps	France
Booz, Horace Corey, Colonel	Railroad Transportation Corps, U.S.N.A.	France
Bostwick, John Vaughan, Capt.	O.R.C., 315th Infantry	Camp Meade
Breed, George, Lieutenant	Fleet Naval Reserve, U.S.N.R.F.	New York
Bunting, C. M., Colonel	E.O.R.C., U.S.A.	France
Cadwalader, Governeur, Major	Ordnance Dept., U.S.R.	
Caldwell, E. W.	Medical Officers' Reserve Corps	
Capps, W. L., Rear Admiral	Chief Constructor, U.S.N., Bureau of Construction and Repair	Washington
Carty, John J., Colonel	Signal Corps, U.S.A.	
Chance, Edwin M., Capt.	Ordnance Dept., U.S.R.	Washington
Clark, Beauvais, Sergeant	108th Field Artillery	Camp Hancock
Clark, E. L., 1st Lieut.	Signal Corps, 401st Telegraph Battalion	Camp Devens
Clark, Theobald F., Capt.	Field Artillery	
Clark, Walton, Jr., Capt.	Field Artillery	
Cornelius, John C., 1st Lieut.	Coast Artillery, U.S.N.A., 13th Company	Sandy Hook
Cottrell, Jas. W., Private	Instruction Section, Ordnance Dept., U.S.A.	Peoria, Ill.
Cowan, Henry B., Sergeant, 1st Class	Co. D., First Telegraph Battalion, Signal Reserve Corps	France
Crampton, George S., Major	Director of Field Hospitals, 28th Div.	Camp Hancock
Cushman, A. S., Lieut. Col.	Ordnance Dept., U.S.N.A.	Frankford Arsenal
Detwiler, Jas. G., 1st Lieut.	Infantry, U.S.R.	Fort Logan H. Roots
Eckert, S. B., Lieut.	Commander 9th Aero Squadron	France
Elliott, Henry M., 1st Lieut.	Ordnance Dept., U.S.R.	Western Cartridge Co.
Emerson, Geo. H., Colonel	In charge of Russian Railway Service Corps	Japan
Felton, Samuel M.	U. S. Director-General of Railways in connection with Expeditionary Force	Chicago

Name and rank	Branch of service	Location
Ferguson, Walter B., Private	21st Co., 154th Depot Brigade	Camp Meade
Fraser, Persifor, Ensign	U.S.N.R.F.	League Island
Gardner, H. A., Senior Lieut.	Naval Flying Corps	Washington
Gfrörer, A. H., 1st Lieut.	Ordnance Dept., U.S.R.	Washington
Gibbons, Joseph E., Private	Co. D., 103rd Engineers	Camp Hancock
Gilbreth, Frank B., Major	Engineers O. R. C.	Washington
Gillmor, R. E., Senior Lieut.	U. S. Navy	New York
Glendinning, Robt. E., Major	Aviation Section, Signal Corps	Overseas
Goodwin, Harold, Jr., Lieut.	Naval Reserve Force	Philadelphia
Gribbel, W. G., Captain	Co. A., 30th Engineers, U.S.R. (Gas and Flame)	France
Griest, Thos. S., 1st Lieut.	1st Telegraph Battalion, Signal Corps, U.S.A.	France
Hall, R. T., Rear Admiral	U. S. Navy, Inspector of Machinery	Cramps' Shipyard
Hodges, Austin L., Capt.	Ordnance Dept., U.S.R., Experimental Officer on Artillery Ammunition	Frankford Arsenal
Howson, Richard, Sergeant	306th Ambulance Corps	Camp Meade
Ives, H. E., Captain	Signal Corps, U.S.A.	Washington
Jackson, John Price, Major		France
Jones, Jonathan, Captain	E.O.R.C., 23rd Engineers	Camp Laurel
Karrer, Enoch, Sergeant	45th Engineers, Company A	Camp A. A. Humphreys
Kennedy, M. C., Colonel	Deputy Director General of Transportation	France
Kent, S. Leonard, Jr., 2nd Lieut.	5th Engineers	Camp Lee
Kingsbury, E. F., 1st Lieut.	Aviation Section, S.O.R.C., Dept. of Science and Research	Washington
LeBoutillier, H. W., Private	Unit No. 10, Pennsylvania Hospital	France
Lichtenberg, Chester, 1st Lieut.	Engineer Reserve Corps, U.S.A.	Washington
Longstreth, Chas., Lt. Commander	U.S.N.R.F.	Philadelphia
McCoy, John F.	Aviation Section, Signal Corps	Princeton
MacLean, Malcolm R., Major	Infantry R. C.	Camp Meade
McMeekin, C. W., Major	Army War College	Washington
Martin, Thos. S., 1st Lieut.	Ordnance Dept., U.S.R.	Washington
Masters, Frank M., Major	Ordnance Dept., U.S.R.	Washington
Maxfield, H. H., Lieut. Col.	19th Railway Engineers, U.S.N.A.	
Mershon, Ralph D., Major	E.O.R.C., U.S.A.	New York
Miller, Fred. J., Major	Ordnance Reserve Corps	Centre Bridge, Penna.
Owens, R. B., Major	Signal Corps	France
Parrish, T. R., Captain	Signal Corps	Washington
Reber, Samuel, Colonel	Signal Corps, U.S.A.	New York
Richardson, Chas. E., 1st Lieut.	30th Engineers, U.S.R. (Gas and Flame)	France
Spackman, Henry S., Major	Engineer Officers' Reserve Corps	France
Spruance, W. C., Jr., Lt. Col.	Ordnance Dept., National Army	Chevy Chase, Md.
Squier, Geo. O., Major General	Chief Signal Officer, U.S.A.	
Stanford, H. R., Civil Engineer	U. S. Navy	Boston
Thomas, Geo. C., Jr., Captain	Aero Service Squadron 96, Aviation Section, Signal Corps	France
Tilghman, B. C., Captain	A.D.C., 28th Div. Headquarters, U.S.A.	

Name and rank	Branch of service	Location
Vogleson, J. A., Major		Camp Jas. E. Johnston
Wagner, Fred. H., Major	Ordnance Reserve Corps, Nitrate Division	Washington
Wagner, Fred. H., Jr. Sergeant	Co. E., 304th Engineers	Camp Meade
Wells, G. A., Captain	Ordnance Reserve Corps	Peoria, Ill.
Wetherill, W. C., Ensign	U. S. Navy	
Widdicombe, R. A., Major	C.Q.M., Chemical Plant No. 4	Saltville, Va.
Wood, Edw. R., Jr., Captain	18th Field Artillery, U.S.N.A.	El Paso, Texas
Worrell, Howard Sellers	3rd Officers' Training Camp	Fortress Monroe
Wyckoff, A. B., Lieut.	U. S. Navy	Ontario, Cal.
Yale, A. W. Major	Medical Reserve Corps, Gas Division	Camp Kearney
Yorke, George M., Major	Signal Corps, U.S.R.	New York

MEMBERS DOING CIVILIAN WORK FOR THE UNITED STATES GOVERNMENT

Name	Appointment	Location
Akeley, Carl E.	Consulting Expert of Mechanical Devices, War Department	Washington
Anderson, Robt. J.	Engineer of Tests of Ordnance, War Dept., U.S.A.	Brier Hill Steel Co.
Balls, William H.	Ships Draughtsman	Phila. Navy Yard
Bancroft, Joseph	Secretary, Local Board No. 1	Wilmington
Baskerville, Charles	Working with Bureau of Mines, Ordnance Dept. (Gas Warfare, Shells, etc.)	New York
Bodine, Samuel T.	Vice-Chairman, District Exemption Board, No. 1, Eastern Judicial District of Penna.	Philadelphia
Brown, Lucius P.	Federal Milk Commission	New York
Burnham, George, Jr.	Dept. of Civilian Service and Relief, Public Safety Committee of Pennsylvania	Philadelphia
Charles, Bernard S.	Ordnance Inspector, U. S. Navy	Allentown, Pa.
Comey, Arthur M.	Chairman, Sub-Committee on Explosives, Chemistry Committee, National Research Council	Chester, Pa.
Condict, G. Herbert	Naval Consulting Board, Member Committee of Examiners	Plainfield, N. J.
Cooke, Morris L.	Chairman, Storage Committee of Munitions Board; Member on Staff, Emergency Fleet Corporation	Washington
Cope, Thomas D.	National Research Council	Washington
Day, Charles	Member of Army War Council	Washington
Delano, Frederic A.	Member of Federal Reserve Board	Washington
Dickie, G. W.	Chief Inspector, U. S. Shipping Board, Moore & Scott Shipyard	Oakland, Calif.
Dunn, Gano	Chairman, Engineering Committee, National Research Council	New York
Garrison, Frank Lynwood	Chairman, U. S. Manganese Commission	Philadelphia
Halberstadt, Baird	Federal Fuel Administrator for Schuylkill Co., Penna.	Pottsville

Name	Appointment	Location
Hoskins, Wm.	Consulting Chemist, Advisory Committee, Bureau of Mines; Associate Member, Naval Consulting Board	Chicago
Hyde, Edward P.	National Research Council, Sub-Committee on Monocular vs. Binocular Field-Glasses (Chairman).	Cleveland
Insull, Samuel	Chairman, Illinois State Council of Defense	Chicago
Kennelly, A. E.	Conducting special course in radio-engineering for the U. S. Signal Corps, in conjunction with Prof. E. C. Chaffee	Harvard Univ.
Lloyd, E. W.	Asst. Secretary, Illinois State Council of Defense	Chicago
Lucke, C. E.	Civilian Director, U. S. Navy Gas Engine School	Columbia Univ.
Merrick, J. Hartley	Director, Bureau of Camp Service, Penna. Div., American Red Cross	Philadelphia
Milne, David	Treasurer, American Red Cross General Hospital No. 1	Philadelphia
Morris, Effingham B.	Treasurer, Committee of Public Safety, State of Pennsylvania	Philadelphia
Nichols, Carroll, B.	Fuel Administration	Washington
Nichols, Wm. H.	Committee on Chemicals, Advisory Council of National Defense, Consulting Chemist, Bureau of Mines	New York
Penrose, R. A. F., Jr.	Member of Geology Committee of the National Research Council	Philadelphia
Rapp, Isaiah M.	Special Investigator of Weights and Measures for the U. S. Food Administration	Norman, Oklahoma
Rautenstrauch, Walter	Committee of the National Research Council	New York
Richards, Joseph W.	Member of Naval Consulting Board	So. Bethlehem, Penna.
Robins, Thomas	Member and Secretary of the Naval Consulting Board	New York
Sperry, Elmer A.	Member of Naval Consulting Board	Brooklyn, N.Y.
Sprague, Frank J.	Member of Naval Consulting Board, Chairman, Committee on Electricity and Shipbuilding	
Stern, Max J.	Supervising Surgeon, Merchant Shipbuilding Corporation	Philadelphia
Stradling, George F.	Recruiting for Aviation Section, S.O.R.C.	Philadelphia
Swenson Magnus	Federal Food Administrator for Wisconsin; Chairman, State Council for Defense	Madison, Wis.
Talbot, Henry P.	Member of Advisory Board, Bureau of Mines (Gas Defense)	Cambridge, Mass.
Thomson, Elihu	National Research Council in coöperation with Council of National Defense	Swampscott, Mass.

Please send additional information and corrections to the Secretary.

COMMITTEE ON SCIENCE AND THE ARTS.

(*Abstract of Proceedings of the Stated Meeting held Wednesday, May 1, 1918.*)

HALL OF THE FRANKLIN INSTITUTE,
PHILADELPHIA, May 1, 1918.

DR. H. JERMAIN CREIGHTON *in the Chair.*

The following reports were presented for first reading:

No. 2707.—Spraco Pneumatic Painting Equipment. Advisory.

No. 2714.—H. C. Snook's Improved X-Ray System.

GEORGE A. HOADLEY,
Acting Secretary.

ANNUAL REPORT OF THE DIRECTOR OF THE SCHOOL.

1917–1918.

COURSES OF INSTRUCTION.

THE ninety-fourth year of The Franklin Institute School of Mechanic Arts closed April 19, 1918. During the year instruction was given in Mechanical Drawing, Architectural Drawing and Design, Freehand Drawing, Shop Arithmetic and Algebra, Plane Geometry and Trigonometry, Applied Mechanics and Strength of Materials, and Naval Architecture.

REGISTRATION.

The total registration for the year was four hundred and eighteen, an increase of 12 per cent. over that of the previous year.

ATTENDANCE AND PROGRESS.

During the first term fifty-four students had a perfect attendance record, and forty-five had a perfect attendance record during the second term. In the regular school work thirty-seven students made an average of 90 per cent. or over during the first term and fifty-six an average of 90 per cent. or over during the second term.

Considering the urgent demand for increased production of war materials and its effect upon the leisure time of the students, the high averages in class work and attendance records indicate that the School of Mechanic Arts has completed a most successful year.

SCHOLARSHIPS.

Twenty-one scholarships were available for students of the School: eleven of these were Bartol Scholarships in Drawing, derived from the B. H. Bartol Fund; ten scholarships were derived from the Isaac B. Thorn Fund, and were awarded to students in Mathematics.

PRIZES.

Valuable prizes were offered by the following gentlemen for meritorious work in the various departments:

Mr. Samuel M. Vauclain, Vice-President, The Baldwin Locomotive Works.

Mr. J. B. McCall, President, Philadelphia Electric Company.

Mr. Wilfred Lewis, President, Tabor Manufacturing Company.

Mr. J. T. Wickersham, Secretary and Treasurer, The New York Shipbuilding Corporation.

Mr. Robert W. Lesley, Past-President, Portand Cement Association, and Member of the Board of Managers of The Franklin Institute.

The Alumni Association continued its special prizes to the graduates having the best records and to graduates having a perfect attendance for the year.

HONORS.

Certificates for the satisfactory completion of a course in one of the departments of Drawing, Mathematics, or Naval Architecture were this year awarded to fifty-two students. Appended are the names of these graduates, also the names of those students to whom were awarded the scholarships and prizes indicated above.

The success of the year that has just closed is due not only to the earnestness of the students and to their continued application to the lessons assigned, but also to the close personal attention and sympathetic interest of the instructors.

Respectfully submitted,

SIMEON VAN T. JESTER,
Director.

April 19, 1918.

LIST OF GRADUATES.

DEPARTMENT OF MECHANICAL DRAWING.

Benjamin Gordon
Charles M. Heron
Edward D. Hoban
John A. Hysore
William Henry Joseph, Jr.
Earl Leroy Lynch
Russell Morehouse
Charles F. Walker
Harry W. Walker
Milton Albert Wike
Joseph H. Wiseman

DEPARTMENT OF AGRICULTURAL DRAWING.

William Nelson Corner
John Dikaski
Lewis Oscar Egbert
David Goldstein
George W. Hardman
B. J. Krakow
James Lambert
Herbert A. Lemke
Jesse J. Moyer
Richard T. Young

DEPARTMENT OF MATHEMATICS.

Joseph P. Battle
Robert C. Black
E. L. Bromall
Charles Buckler
M. E. Chance
Harry J. Daubenschmidt
Florian R. Deppe, Jr.
Joseph Friedman
Thomas Charles Gatley
George Alvin Gieseke
Russell H. Harden
Andrew Hetherington
Robert B. Hetherington
John H. Hughes
William Kuenstle
Cyril Leech
Fred A. Niethamer, Jr.
Earl N. Rich
William F. Sanders
Albert T. Schleicher
Francis J. Sommer
Charles W. Stanley
Robert G. Staples, Jr.
John A. Stewart
Anthony Voll
Charles F. Wagner
Elmer Zeisloft

DEPARTMENT OF NAVAL ARCHITECTURE.

A. E. Copeland
Theodore G. Grier
Jacob Klonin
John L. Starr

BARTOL SCHOLARSHIPS.

DEPARTMENT OF DRAWING.

Samuel H. Collins
Ray Douglas
Francis A. Harden
Dugmore Jones
George Nairn
Franklin Oergel
John Pollano
Harry H. Riley
Harry Scott
Earl R. Watt
J. Wesley Whitehead

ISAAC B. THORN SCHOLARSHIPS.

DEPARTMENT OF MATHEMATICS.

Howard Cornwall
Fred Howarth
William Kuenstle
John McClelland
Kempton McNutt
Earl N. Rich
Herman Schaaf
Wilson D. Scott
Stanley K. Weber
Benjamin A. Wilson

PRIZES.

Earl L. Lynch—S. M. Vauclain Prize—Mechanical Drawing.
Richard T. Young—Robert W. Lesley Prize—Architectural Drawing.
J. A. Keohane—Wilfred Lewis Prize—Mechanics.
Thomas C. Gatley—J. B. McCall Prize—Mathematics.
Theodore G. Grier—New York Shipbuilding Company Prize—Naval Architecture.

ALUMNI PRIZES.

Thomas C. Gatley
William H. Joseph, Jr.
Richard T. Young
J. A. Keohane
Theodore G. Grier

FREE MEMBERSHIP FOR ONE YEAR IN THE ASSOCIATION AWARDED TO GRADUATES.

Robert C. Black
M. E. Chance
Harry J. Daubenschmidt
Lewis Oscar Egbert
Thomas Charles Gatley
Theodore G. Grier
George W. Hardman
Charles M. Heron
William Henry Joseph, Jr.
Jacob Klonin
William Kuenstle
Earl Leroy Lynch
Russell Morehouse
Jesse J. Moyer
Albert T. Schleicher
Charles W. Stanley
John L. Starr
Anthony Voll
Charles F. Walker

MEMBERSHIP NOTES.

ELECTIONS TO MEMBERSHIP.

(Stated Meeting, Board of Managers, May 8, 1918.)

RESIDENT.

Mr. Walter C. Holmes, Chief Chemist, Superior Thread and Yarn Company, Howard and Norris Streets, Philadelphia, Pa.

CHANGES OF ADDRESS.

Mr. Arthur N. Blum, Delmar-Morris Apartments, Germantown, Philadelphia, Pa.
Mr. William H. Crago, 123 Sylvan Avenue, Leonia, N. J.
Dr. Ernst Fahrig, 117 North Massachusetts Avenue, Atlantic City, N. J.
Mr. William J. Fitzmaurice, Jr., 747 Marlyn Road, Philadelphia, Pa.
Mr. P. M. Kuehn, Linthicum Heights, Lansdowne, R. F. D., Md.
Mr. Peder Lobben, Room No. 2, Keysersgade 1, Christiana, Norway.
Dr. Edward E. Marbaker, 622 Marlyn Road, Philadelphia, Pa.
Mr. Robert Ridgway, care of Public Service Commission, 49 Lafayette Street, New York City, N. Y.
Mr. C. S. Vadner, Box 594, Reno, Nev.
Mr. H. H. Vaughan, 20 MacGregor Street, Montreal, Quebec, Canada.

NECROLOGY.

Frank Shuman was born in Brooklyn, N. Y., in 1861, and died at his home in Philadelphia on April 28, 1918.

He was educated in the common schools of his native city, and later graduated from Lafayette College.

Mr. Shuman was best known for his inventions relating to the application of the sun's heat as a motive power. His solar engine has had its widest application in Egypt because of the great amount of sunshine in that country throughout the year.

He devised a machine for mercerizing cotton and another for degreasing wool.

Mr. Shuman was the originator of wire glass, and for this invention the city of Philadelphia awarded him the John Scott Legacy Medal in 1894 on the recommendation of the Institute. Ten years later he received further recognition from the city of Philadelphia for his concrete pile for foundations.

Mr. Shuman became a member of the Institute in 1893.

LIBRARY NOTES.

PURCHASES.

American Ceramic Society.—Transactions, vol. 19. 1917.

American Society of Heating and Ventilating Engineers.—Transactions, vol. 23. 1917.

Book Review Digest.—13th Annual Cumulation. 1917.

FAHRENWALD, A. W.—Testing for the Flotation Process. 1917.

American Institute of Architects.—Structural Service Book, No. 1. 1918.

KOZMIN, P. A.—Flour Milling; a Theoretical and Practical Handbook of Flour Manufacture. 1917.

MARTIN, GEOFFREY, and Others.—Industrial Gases, Including the Liquefaction of Gases. 1916.

MURRAY, J. A. H.—New English Dictionary on Historical Principles, vols. 3–9. 1901–1914.

Poor's Manual of Industrials.—Annual, No 9. 1918.

PRIDEAUX, S. T.—Aquatint Engraving; a Chapter in the History of Book Illustration. 1909.

RUNNING, T. R.—Empirical Formulas. 1917.

TASHIRO, SHIRO.—Chemical Sign of Life. 1917.

United States Catalogue Supplement.—Cumulative Index, vol. 20. 1917.

VIALL, ETHAN.—Broaches and Broaching. 1918.

WAITE, A. E.—Lives of the Alchemystical Philosophers. 1888.

World Almanac and Encyclopedia. 1918.

BOOK NOTICES.

THE SCIENCE AND PRACTICE OF PHOTOGRAPHY: AN ELEMENTARY TEXT-BOOK ON THE SCIENTIFIC THEORY AND A LABORATORY MANUAL. By John R. Roebuck, Ph.D. New York, D. Appleton and Company, 1918, 287 pages, contents and index, illustrations, 8vo. Price, $2.00.

There is a great deal of useful information for photographers, both professional and amateur, in this book. As the author is a teacher of physics, it has been given more the character of a student's text-book than a reference work, but this does not interfere with its usefulness. The course, as outlined, requires an elementary knowledge of mathematics, physics, and chemistry. The author is, doubtless, right in criticising unfavorably the reliance of many photographers upon empirical methods, and neglecting the theory of the processes. Those who are to-day acquainted with the aims of photographic exhibitions know well how little the technical side of the science attracts. In these exhibitions, and in the slide-interchanges of the American photographic societies, a picture that shows some phase of pure technic, such as development after fixing, pinhole work, reversal of image, is passed over by the judges, and the first prize is apt to go to a picture that is about as vivid when upside down as in the proper position.

The book opens with a historical introduction, in which the work of Niepce, Daguerre, and Talbot leads off; then follow paragraphs on collodion, gelatin, and the dry-plate. An interesting account is given of the methods of manufacture of the common dry-plate emulsions. The properties of the gelatin plate are treated extensively, including the theory of the latent image, after which follows a consideration of the ordinary defects of negatives, with which beginners, and even some old hands, are only too familiar. The making of positives is then taken up, after which the theory of lenses is discussed. Color photography and the general principles of artistic picture-making are included in the next chapters. After consideration of development and speed data, sixty pages are devoted to the "Laboratory Manual," which is a series of valuable experiments in photographic procedure.

The book is well printed with large, clear type, and freely illustrated, mostly with line drawings. The photogravures are generally poor. The frontispiece, which is intended to illustrate autochrome work, is, in the copy in the reviewer's hands, so badly out of register as to be worthless. A reproduction of a pinhole picture is given, but here again the mechanical execution of the plate is poor and the view chosen is not at all adapted to show the capacities of such methods for artistic work. Architecture is often very attractively rendered by the pinhole; indeed, it is generally conceded that the perspective is better than that yielded by most lenses. Another interesting feature of pinhole work is that views may be taken where there is rapidly-moving traffic, without this interfering with the picture.

HENRY LEFFMANN.

LABORATORY GUIDE TO INDUSTRIAL CHEMISTRY. By Allen Rogers. New York, D. Van Nostrand Company, 1917. Second edition, entirely rewritten and enlarged. 204 pages, contents and index, illustrations, 8vo. Price, $2.00 net.

The author, in the preface, states that this book is a plea for a more extended teaching of industrial chemistry in technical schools, and it is well calculated to serve this purpose, for it contains a large amount of information of the most practical character. It presumes that the student possesses a knowledge of the general principles of chemistry, which is, of course, a proper view, for no student should take up such work unless quite familiar with the modern theories of chemical action, and especially with stoichiometry.

The topics covered by the book are: General Process, Inorganic Preparations, Organic Preparations, Dyeing of Textiles, Pigments and Lakes, Driers, Varnishes, Paints and Stains, Soap and Allied Products, Leather, Woodfibre, Pulp and Paper. Ten pages of Useful Data, including tables and rules for certain calculations, close the book. The work is, of course, useful only to the student, not being intended to take the place of the large reference works in this field. It is well printed.

HENRY LEFFMANN.

REPORT ON THE PROGRESS OF APPLIED CHEMISTRY, issued by the Society of Chemical Industry, vol. 1, 1916. London, Harrison and Sons, 1917. 315 pages and index. 8vo. Price, 5s. 6d.

The *Journal of the Society of Chemical Industry* has been for so many years favorably known to chemists interested in the practical phases of the science that the present volume will need no special recommendation. It is a new venture, and is not a collection of abstracts or a reprint of articles from the *Journal,* but independent reports of specialists giving the more important developments, up to the end of 1916, in many departments of applied chemistry. Agricultural and food chemistry, and analytic methods as such, are not included, as these are treated in the reports of the Chemical Society. For obvious reasons, explosives are not considered in the present volume. The book is well printed, contains a large amount of highly valuable data, and its appearance, as the initiator of the series, will be good news to chemists.

HENRY LEFFMANN.

PRINCIPLES OF AGRICULTURAL CHEMISTRY. By G. S. Fraps, Ph.D. Easton, Pa., Chemical Publishing Company, 1917. Second edition, 490 pages, contents and index, illustrations. 8vo. Price, $4.50.

Few phases of chemistry are to-day more important than the agricultural. The citizen sees staring at him from almost every point available the slogan "Food will win the war," and every one knows that the source of all food is the earth. Extensive as have been the studies of the chemistry of growing crops and of animal development, much still remains to be done in this field. In the main, the farmer is not fully alert to the more recent science, and many parts of the earth still fail to yield the return that theory indicates and that the labor bestowed on them should procure.

The work before us is a comprehensive statement of the principal phases of the chemistry of plant growth, nature of soils, composition and value of fertilizers, processes of animal digestion, and practical directions as to the methods of feeding food animals and of conducting studies in both plant and animal nutrition. Some information is given as to procedures in analysis; but the book has not been written as an analytic manual nor as a treatise on chemistry. There are nearly one hundred illustrations, many of which are commendable, some not so, some indeed essentially useless. The pictures of an Alpine glacier (p. 56), a limestone cavern (p. 58), and of the sections of porphyry and granite (p. 64) are not ornaments to the book. Similarly, the cheap cut of polarimeter (erroneously called polariscope) was not worth printing.

The reviewer regrets that the author has been careless as to chemical nomenclature. The term "proteids" is now generally abandoned for the term "protein," and it is a mistake to say that feldspars "contain potash, soda, and lime." They yield these substances under certain treatment, but do not contain them. It is true that many farmers and dealers use such terms, but this book is intended for the instruction of scientists, and should observe the scientific forms.

The book is well printed and contains a large amount of valuable information.

HENRY LEFFMANN.

LECITHIN AND ALLIED SUBSTANCES, THE LIPINS. By Hugh Maclean, M.D., D.Sc. London, Longmans, Green & Co., 1918, 206 pages, 8vo. Price, $2.25.

This treatise is one of the series of monographs on biochemistry edited by R. H. A. Plimmer and F. G. Hopkins. Maclean uses the term lipin as a class name to include the phosphatides (substances containing fatty acids, nitrogen, and phosphorus) and the cerebrosides (substances containing fatty acids, nitrogen, and a carbohydrate group, but no phosphorus), and offers the following definition: "Lipins are substances of a fat-like nature yielding on hydrolysis fatty acids or derivatives of fatty acids and containing in their molecule either nitrogen, or nitrogen and phosphorus." The phosphatides recognized as chemical entities are: lecithin and kephalin (monaminomonophosphatides), sphingomyelin (a diaminomonophosphatide), and cuorin (a monaminodiphosphatide); the cerebrosides recognized as chemical entities are phrenosin and kerasin. One chapter is devoted to the chemistry of the phosphatides, another to their occurrence, and the methods used for their extraction, isolation, and purification. The cerebrosides and protagon are discussed with the same detail as the phosphatides. Protagon is defined as "certain mixtures of cerebrosides and sphingomyelin obtained from organs by extraction with hot alcohol and other solvents. For this purpose it is perhaps worth while retaining a name which has ceased to have any meaning in the chemical sense, but is of some importance from the practical point of view." Alleged lipins and plant lipins receive attention in separate chapters.

The concluding chapter describes the function of lipins, their relation to metabolism, growth, narcosis, and certain oxidative processes (oxydases and respiration of plants), and also their action on digestive enzymes. The author was called to France before the completion of this chapter, and it became necessary to omit a section on the phenomena of hæmolysis and immunity, or else to postpone publication indefinitely. The conclusion is reached that, at present, the special part played by the lipins in the activity of the organism is entirely unknown to us.

A bibliography of 22 pages is appended.

JOSEPH S. HEPBURN.

ALLEN'S COMMERCIAL ORGANIC ANALYSIS. Edited by W. A. Davis. Fourth edition, volume IX. Philadelphia, P. Blakiston's Son & Co., 1917, 836 pages, 8vo. Price, $5.

This volume forms a supplement to the preceding eight volumes. Its purpose is given in the preface: "Since the revision of this work was first undertaken in 1907, a considerable amount of literature has appeared and many new methods of analysis have been devised. It, therefore, became desirable to issue a supplementary volume bringing the text, especially that of the earlier volumes, up to date. The new articles have, as far as possible, been written by the contributors to the earlier volumes, but, in a few cases, pressure of other work caused by the outbreak of war has made it necessary to entrust the revision to other hands." The new contributors are: A. J. Ewins, K. G. Falk, P. B. Hawk, R. Lessing, R. H. McKee, J. R. Powell, P. J. Sageman, J. P Street, Arthur W. Thomas, and J. B. Tuttle.

The volume is divided into sections on: Alcohols; malt and brewing materials; wines and spirits; yeast; neutral alcoholic derivatives; sugars: starch and its isomerides; paper and paper making materials; aliphatic acids; fixed oils, fats and waxes, their special characters and modes for their examination; butter fat; lard; linseed oil; soaps; glycerol; cholesterol; wool, grease and cloth oils; hydrocarbons, bitumens; naphthalene and its derivatives; phenols; aromatic acids; resins; india-rubber, rubber substitutes and gutta-percha; essential oils, and their special characteristics; tannins; leather analysis; coloring matters, their analysis, those of natural origin, and those in foods; inks, and printing inks; amines and ammonium bases; aniline and the naphthalamines and their allies; vegetable alkaloids (separate chapters on volatile alkaloids; those of aconite, opium, strychnos, and cinchona; atropine and its allies; cocaine; berberine and its associates; caffeine, tea and coffee; and other alkaloids): glucosides; non-glucosidal bitter principles; animal bases and acids; lactic acid; cyanogen derivatives; enzymes; proteins, with chapters on those of vegetable origin and of milk; milk products; albuminoids; meat and meat products; and fibroids. Additional supplementary matter is given in an appendix. Besides an index to Volume IX, a general index is included, covering the entire set of nine volumes, authors and subjects being listed separately.

JOSEPH S. HEPBURN.

THE PHYSICAL CHEMISTRY OF THE PROTEINS. By T. Brailsford Robertson, Ph.D., D.Sc. New York, Longmans, Green & Co., 1918, 483 pages, 8vo. Price, $5.00 net.

In the preface Robertson states: "I have endeavored to interpret the physico-chemical behavior of the proteins in the light of the laws of Boyle and Gay-Lussac, as they have been applied to solutions by van 't Hoff, and of the Guldberg and Waage mass-law, which, as Larmor has shown, is a direct consequence of Avogadro's rule and Boule's Law. I have also assumed the validity, in protein systems, of the first and second laws of heat; albeit the applicability of the second law of heat to protein systems has, in some quarters, been questioned. In considering the *electrochemical* behavior of the proteins I have assumed the applicability of Arrhenius' hypothesis of electrolytic dissociation, of Kohlrausch's law of the independent motion of ions, of the Nernst theory of concentration-cells, and further, although this has of recent years been very strongly questioned, the applicability of the Guldberg and Waage mass-law to reactions between ions. I believe that the utility of these hypotheses justifies us in applying them until still more useful hypotheses shall have been elaborated to amplify or replace them."

The treatise is divided into four parts. Part I, Chemical Statics in Protein Systems, includes chapters on the chemical constitution of the proteins, their preparation in the pure state, their quantitative estimation, and their compounds with other compounds—inorganic, organic, and biological—acid, basic, and neutral. Part II, The Electrochemistry of the Proteins, is devoted to chapters on the formation and dissociation of protein salts, the combining capacity of the proteins, the electrical conductivity of their solutions, and the electrochemistry of coagulation. Part III, The Physical Properties of Protein Systems, opens with a discussion of the phenomena accompanying the changes in the state of aggregation of proteins; the optical and other physical properties of protein solutions are then described. In Part IV, Chemical Dynamics in Protein Systems, attention is paid to the hydrolysis of the polypeptides and the proteins, and to the enzymatic synthesis of proteins. The technic of electrochemical measurements in protein systems is discussed in an appendix. Subjects and authors are indexed separately. A bibliography is given at the end of each chapter, covering the literature to the middle of the year 1917.

JOSEPH S. HEPBURN.

PUBLICATIONS RECEIVED.

The Chemical Analysis of Iron: A complete account of all the best-known methods for the analysis of iron, steel, pig-iron, alloy metals, iron ore, limestone, slag, clay, sand, coal, and coke, by Andrew Alexander Blair. Eighth edition. 318 pages, illustrations, 8vo. Philadelphia, J. B. Lippincott Company, 1918. Price, $5.

James Woodhouse, a Pioneer in Chemistry, 1770–1809, by Edgar F. Smith, Provost of the University of Pennsylvania. 299 pages, plates, portrait, 12mo. Philadelphia, John C. Winston Company, 1918.

Cours de Mécanique professé a l'école polytechnique par Léon Lecornu, tome iii. 668 pages, illustrations, 8vo. Paris, Gauthier-Villars, 1918. Price, 25 francs.

Lecithin and Allied Substances: The Lipins, by Hugh Maclean. 206 pages, 8vo. New York, Longmans, Green and Company, 1918.

North Carolina Geological and Economic Survey: Economic Paper No. 46. The Vegetation of Shackelford Bank, by L. F. Lewis. 40 pages, plates, 8vo. Economic Paper No. 47, Proceedings of the Ninth Annual Drainage Convention of the North Carolina Drainage Association, held at Greensboro, North Carolina, November 22 and 23, 1916, compiled by Joseph Hyde Pratt, State Geologist, and Miss H. M. Berry, Secretary. 110 pages, illustrations, 8vo. Raleigh, State Printers, 1917.

U. S. Bureau of Mines: Bulletin 103, Mining and Concentration of Carnotite Ores, by Karl L. Kithil and John A. Davis. 89 pages, illustrations, plates, 8vo. Bulletin 137, The Use of Permissible Explosives in the Coal Mines of Illinois, by James R. Fleming and John W. Koster. 110 pages, plates, 8vo. Bulletin 155, Oil-storage Tanks and Reservoirs, with a Brief Discussion of Losses of Oil in Storage and Methods of Prevention, by C. P. Bowie. 76 pages, illustrations, plates, 8vo. Monthly Statement of Coal-mine Fatalities in the United States, January, 1918. List of Permissible Explosives, Lamps, and Motors Tested Prior to February 28, 1918, compiled by Albert H. Fay. 23 pages, 8vo. Coal-mine Fatalities in the United States, 1917, compiled by Albert H. Fay. List of Permissible Explosives, Lamps, and Motors Tested Prior to January 31, 1918. 37 pages, 8vo. Washington, Government Printing Office, 1917–1918.

Non-inflammable Plastic Material. ANON. (*The Chemical Trade Journal and Chemical Engineer,* vol. lxi, No. 1589, p. 365, November 3, 1917.)—A recent French patent describes a new plastic material which is non-inflammable and odorless. The material is obtained by transforming gelatines, glues, and such substances of animal origin by suitable chemical reagents, giving them plastic and malleable properties which allow them to be used industrially in a manner similar to natural products.

The gelatines or glues are first melted in a water-bath at a temperature of 90° C. A decoction of hop flowers is then prepared and mixed with dilute oxalic acid or any dibasic acid of that series, and the solution is added to the melted gelatines or glues in varying proportions, according to the quality of the materials employed. The addition of this solution has the effect of rendering the gelatine more supple and of causing the impurities they contain to deposit at the bottom of the vessel. When the gelatines are liquefied they are poured out in the form of sheets or sticks of the desired thickness and left to dry in the cold air. The coloring of the material is then proceeded with, natural or artificial dyes being employed. The sheets, when colored, are plunged into a bath of approximately the following composition: 25 to 35 per cent. formaldehyde, 25 to 35 per cent. water, 25 to 35 per cent. alcohol, and the rest composed of a mixture of oxalic acid, tannin, and glycerine.

The oxalic acid may be replaced by any other acid of that series. The plates should be left in this solution until the liquid has penetrated into the entire plastic mass. In the case of rich gelatines, the proportion of alcohol must be increased. The sheets, when taken out of the bath, are dried, preferably in hot air. The substance, when suitably worked, may serve for the manufacture of combs, buttons, brushes, etc., as an imitation of tortoise shell, horn, amber, or ivory, and is unlike other cellulose products used in industry, in being absolutely non-inflammable and odorless.

CURRENT TOPICS.

Colored Silk Effects on Cloth. ANON. (*The Dyer and Calico Printer,* vol. 88, No. 454, p. 227, December 15, 1917.)—Silk effects have been produced in printing by means of finely powdered metal suspended in a binding medium. With all its advantages, this method has two drawbacks, the first being that among the metallic powders available for such purposes there is not a single one that is actually white; that chiefly employed for the purpose, aluminum powder, is grayish blue. The consequence of this is that in using metallic powder processes it is not possible to produce a pure white on light substances. It is only on dark substances by contrast that the effects printed with metallic powders appear white. The second drawback is the impossibility of printing any particularly desired tints with metallic powder, the printing being restricted to such shades of color as are found in the aniline colors. The metallic powders colored with coal-tar colors, moreover, owing to the colors lying only on the surface, have the disadvantage that, when rubbed, the color is removed and the metal beneath exposed. Coloring the binding medium is not practicable, as this is not easily colored, and the metallic powders suspended in the medium, which are colored with great difficulty, alter the color, and in certain circumstances entirely nullify the effect.

To overcome these faults an Austrian chemist has invented a process by which it is possible to obtain silk-like, glossy effects in pure white or in any color. The method is based on the principle of mutual action of cellulose and cellulose derivatives and finely powdered mica. The employment of mica adhesively attached to woven materials is well known, but the gist of the new process is the highly effective and in every respect genuine result produced by the combined action of mica and cellulose derivatives. If an impression is made on a ground with a solution of cellulose nitrocellulose, viscose, or acetate of cellulose, in no instance is a silk effect produced either with or without subsequent calendering. The ground shows through the transparent impression and the desired effect is not produced.

By the addition of a substance producing non-transparency, for example, a powdered white coloring body, no better result is obtained than by using the white coloring body in combination with another binding medium. On the other hand, it can easily be shown that finely powdered mica in ordinary media does not produce silk-like, glossy effects. Neither gelatin nor albumin, the carbohydrates still employed as media, solutions of resin, or any kind of varnish produce satisfactory glossy, silk-like effects, as these binding media more or less completely obscure the lustre of the mica. Only by the employment of mica in combination with cellulose, nitrocellulose, viscose, and other derivatives of cellulose are silk-like, glossy effects produced. It is expressly pointed out that cellulose and its derivatives do not act exclusively as binding or fixing media for the finely powdered mica; the mica could be equally well fixed, or in certain instances even better, with other fixing media—for example, gelatin, albumin, varnish, and solutions of resin. What is actually under consideration is the combined action of the mica with the cellulose derivatives which are known to possess a silk-like lustre. As the solutions of cellulose derivatives can easily be colored without injuriously affecting their lustre and that of the mica when the drying is effected, and without having their tints undesirably modified by the mica, it is possible to produce colored, silk-like, lustrous printing effects, the tints of which are entirely under the control of the colorist. The process consists in dissolving the cellulose or its derivatives and mixing it, colored or uncolored, with finely powdered mica, and printing upon the ground with the resulting paste. The following proportions give good results: 100 parts by weight of a 15 per cent. solution of nitrocellulose (nitrate of cellulose), pyroxyline, collodion cotton, etc., in a suitable solvent, as amylacetate, butylacetate, etc., to which a small quantity of a softening medium, as castor oil or glycerine, may be added, are thoroughly mixed with 8 to 10 parts in weight of finely powdered mica.

Photographic Surveying in Canada. ANON. (*British Journal of Photography*, vol. 65, No. 3009, p. 5, January 4, 1918, from *Geographical Review*.)—Photographic surveying may be used in any class of country where the topographical features are sufficiently marked to appear clearly in the photographs. The method, however, is best adapted to rugged country, such as the high mountain ranges of British Columbia and Western Alberta. Here the season during which climbing may be accomplished with safety is short, and climatic conditions are often unfavorable. High winds, storms, clouds, and extreme cold are the rule, so that work must often be done hurriedly and under great difficulty.

On Canadian photographic surveys the essential instruments are a camera and a small transit. These instruments are of the simplest possible form. In this respect they show a marked contrast to the complicated designs of most European instruments. The camera consists of an oblong metal box, open at one end and fitted into a strong outer wooden case. The metal box carries the lens and two sets of cross-levels, and views may be made with the long side of the plate either horizontal or vertical. The instrument stands on a three-screw base identical with that of the transit, so that the same tripod may be used for both. The size of the plates is 6¾ x 6½ inches. Owing to the excessive contrasts of Alpine scenery, orthochromatic plates and a color screen are essential.

When in the field it is important to select those points which give the best views of the surrounding country. It is customary to take enough views from each peak to cover the complete circuit of the horizon. It seldom happens, however, that all the views can be taken from a single point. Usually a number of camera stations are required on different parts of the peak, and located by reading angles on them from the central point and measuring the distance with a light tape. Angles of elevation or depression should also be read at these points to check the horizon line.

For plotting purposes bromide enlargements, approximately 10 x 14 inches, are made from the negatives. This must be very accurately done to obtain satisfactory results. Views from different stations showing the same country are selected, and sufficient points are identified on each of two corresponding views, taken from the different stations, to show the topography of the country. These points are then plotted on the plan and their elevations calculated from the photographs.

Cleaning Mill Spots from Silks. ANON. (*American Silk Journal,* through *The Dyer and Calico Printer,* vol. 88, No. 454, p. 234, December 15, 1917.)—Almost from time immemorial there has been more or less trouble experienced in cleaning and spotting silks soiled in the mill in the process of manufacturing. Because of the peculiar structure of silk, the inorganic matter which is frequently put into it, and the fact that the dyes are not always fast, it is difficult to use spotting agents without leaving rings or other discolorations in attempting to remove oil or grease spots or stains, however caused. Spotting solutions used for cleaning purposes should not contain alcohol or ammonia. Some of the basic dyes used for silks are very sensitive to alcohol, and ammonia discolors white and light-tinted silks. Notwithstanding that even a harmless bit of white soft silk waste may be used for cleaning, the silk fabric should never be rubbed on its face. All spots should be removed from the back of the cloth with the face of the material on a clean white cotton or woollen cloth or white blotting-paper, which will attract the spot from the silk by absorbing it.

Every precaution should be taken against leaving rings on the silk when using spotting agents. For instance, when benzine is used for cleaning, it should be strained through salt to remove the moisture. A funnel may be used for this purpose, over which a piece of clean white cotton cloth is laid to hold the salt. Before using, the benzine should be filtered through the salt. Chloroform readily removes oil and grease stains from white silks. Used on dyed silks, it is apt to affect the color. Carbon tetrachloride is recommended for colored silks. If these reagents are used in a warm condition, they evaporate quicker from the silk. Paint stains may be removed from silks by aniline oil, followed by ether. Ink spots are sometimes affected by a dilute solution of oxalic acid after alcohol has been tried. Acetic acid used for removing ink stains will be found less harmful to colors than oxalic acid. Slight steaming will remove water spots from silk.

Fixation of Nitrogen. H. LEFFMANN. (*Transactions of the Wagner Free Institute of Science,* vol. 8, July, 1917.)—The amount of nitrogen in the part of the universe with which we are acquainted is immense, much of it being in the free state in the atmosphere. In view of the possible near-exhaustion of the sodium nitrate deposits of South America, and the slowness with which nitrates can be produced by ordinary methods of decomposition, agricultural chemists have for some years been turning their attention to the discovery of methods of causing the nitrogen of the atmosphere to unite with other elements so as to produce compounds that may be employed for enriching the soil. These processes are also invaluable in another department of human industry; namely, the manufacture of explosives.

A peculiar and interesting utilization of nitrogen takes place in soil, in connection with the growth of some plants, especially those belonging to the large and widely distributed natural order, *Leguminosæ*. To this order belong several important food plants, such as peas and beans; important grazing plants, such as clover and alfalfa, and many trees, such as the honey-locust, the Kentucky coffee-tree, and the acacias. The roots of many of these plants bear nodules that are collections of bacteria, which use the roots as a physical support and carry on processes by which nitrogen is fixed and rendered available for the use of the host plant. It has long been known that the fertility of land can be materially increased by planting clover and plowing it in after it has reached good growth. These processes of nitrogen-fixation are slow, and the nitrogen compounds must be utilized in the place in which they are produced for the growth of plants, so that one very important application of fixed nitrogen, that for the manufacture of explosives, is not met by this method.

Nitrogen was formerly considered one of the most indifferent of elements, but research has brought to light a few elements—gases at ordinary temperatures and existing in small amount in the air—which are apparently without chemical affinity. Free nitrogen combines directly, even under the influence of high temperature, with but few elements, of which one is magnesium. Under the influence of the electric spark, direct combination of the nitrogen and oxygen of the atmosphere can be effected. This was discovered in the eighteenth century, in the course of researches by Henry Cavendish and Joseph Priestly. Whether the combination is due to the increase of the affinity of the nitrogen or the oxygen, or both, is not definitely known. It is known that pure oxygen can be converted by electric discharges, especially the so-called " silent discharge," into the much more active form, termed " ozone," without an alteration in fundamental composition. Cavendish used the spark of a static machine, and some modern apparatus for producing ozone use discharges of high voltage currents, either through a special dielectric or directly through dry air.

The direct oxidation has been carried out in several ways, but present usage is limited to the flaming arc. One of the best known and apparently most successful forms of apparatus is the Birkland-Eyde furnace, which depends on developing an arc by an alternating current of high voltage in a constant magnetic field, the arc spreading out under the influence of the magnetic field in the form of a fan at each electrode. As current can easily be obtained at low cost by water power, the operation of such plants has been especially developed in mountainous countries, such as Switzerland and Scandinavia. Abundant opportunities for such development exist in the United States.

Calcium carbide has been manufactured for many years in large amount for the production of acetylene; when this compound is heated to about 1000° C. in a current of nitrogen, direct combination takes place, with the formation of calcium cyanamide. Calcium cyanamide may be used directly as a fertilizer, and, as it contains 4 per cent. more of available nitrogen than sodium nitrate, it is being prepared on a very large scale. This product is marketed in a finely powdered form, often under the name "nitrolim." The process is carried out either by heating the carbide by means of an electric arc within the mass, or in retorts by direct outside firing. The cyanamide processes differ from the nitrogen-oxidation processes by the fact that the former require practically pure nitrogen, while in the oxidation processes the raw material is air, which is obtainable in unlimited amount. The fertilizing action of calcium cyanamide is dependent essentially upon its power of yielding ammonium compounds under the influence of moisture, with probably the coincident action of soil bacteria.

Synthetic ammonia may be produced by the direct action of nitrogen and hydrogen in a high state of purity. Their union is accomplished by the joint action of heat pressure and a catalyst. The practical investigation of the synthetic production of ammonia is due to Haber and Le Rossignol. They found that by employing a pressure of about 200 atmospheres, a temperature between 500° and 700° C., and passing the gases over a catalyst, from 3 to 12 per cent. of ammonia could be obtained. The technical difficulties of manipulation involved in this process appear to be serious, and the record of its achievement is not favorable, at least in its present state of development.

Recently another process of nitrogen-fixation devised by Prof. John F. Bucher has been announced. Briefly, this consists in passing air over heated coal or coke previously mixed with an alkali, and with finely divided iron, which acts as a catalyst. An alkali cyanide results. (See this JOURNAL, May, 1917, p. 665.)

Photographic Resolving Power. K. HUSE. (*Journal of the Optical Society of America*, vol. 1, No. 4, p. 119, July, 1917.)—Photographic resolving power is generally defined in terms of the distance by which two minute images lying adjacent to one another are just separated on the developed plate. In the judgment of the separation it is assumed that the image is so viewed as to be well within the resolving power of the eye and not magnified to an extent that will make the individual silver grains more apparent than their groupings. This is a logical definition, strictly in accord with that of the resolving power of optical instruments, but it should be pointed out that the measurement of photographic resolving power is not an angular measurement, but a linear one.

The method employed of determining this resolving power is that devised by Mees, and consists in accurately photographing a test-object, a fan-shaped converging grating, divided into alternate light and dark sectors, each including an angle about 1.5 degrees. The minute image thus obtained, only one millimetre long, is examined under a micrometer microscope to ascertain the distance from its apex the image is resolved. The spacings of the grating and the scale of reduction being known, a numerical expression for the resolving power is found. Thus a value of fifty means that the plate or film under the conditions of the experiment is capable of resolving fifty lines to the millimetre, measured from centre to centre.

Photographic resolving power has been studied by the fan-grating test to ascertain the effect of exposure, development, developer used, and the wave-length of the incident light. It was found that resolution is, in general, extremely sensitive to time of exposure, over- and under-exposure being decidedly detrimental. It also depends upon the time of development and upon the reducing agent employed. If two plates of the same emulsion, exposed equally and under the same conditions, are developed in different developers, the values of resolving power obtained vary widely, the greatest deviation from the maximum value being of the order of forty per cent. with the developers tested. Thus resolution is not a definite property of an emulsion, but it is dependent also upon its treatment in the photographic process. With regard to the effect of the wave-length of the incident light, resolution was best for light of the short wavelengths, with a decided minimum in the green, increasing again in the red, though not to as high a value as with blue light.

Placer Platinum in California and Oregon. ANON. (U. S. Geological Survey, *Press Bulletin,* No. 356, February, 1918.)—Platinum, osmium, iridium, palladium, ruthenium, and rhodium form a group of closely related metals, which are generally found as native metals more or less alloyed with one another. They are rarer than gold, and some of them, especially platinum, iridium, and palladium, are now more valuable and in greater demand than gold. Under normal conditions the United States requires about 165,000 ounces of the platinum metals a year. It produces only a few thousand ounces, and is meeting increasing difficulties in importing sufficient quantities. Therefore these metals should be applied only to their most essential uses.

The platinum metals are found in quantities of economic value at only a few places. The bulk of the world's production has heretofore been furnished by the placers of the Ural Mountains, in Russia, but the production from this source is decreasing. Colombia is becoming an increasingly large producer. In the United States there has been a small but steady production of platinum for many years from the gold placers of northern California and southern Oregon.

In these new emergencies we find that we have not utilized all our natural resources and that we have lacked the imagination to foresee the value of some of these resources. Henry G. Hanks, a former State mineralogist of California, as far back as 1884 made the following statement: "If the miners could be persuaded to collect the platinum minerals an industry might be established of considerable importance. There is no reason why platinum should not be manufactured in San Francisco and the American demand in part or wholly supplied by this state." It is said that the platinum metals were thrown away by the miners in the early days because there was no demand for them. The things that are thrown away by one generation, however, are picked up and saved by the next, and the work of saving these valuable metals is now in progress.

In view of the increasing difficulty of obtaining sufficient supplies of these metals a comprehensive survey of our platinum resources was begun by the United States Geological Survey, Department of the Interior, during the field season of 1917. The work in California was done in coöperation with the California State Mining Bureau. Most of the platinum that has been produced in the world has come from placer mines, and much of it has been derived from placers that were worked primarily for their content of gold, such as those in California and Oregon. In these places the platinum metals are associated with the gold. The important facts regarding their occurrence are their widespread distribution and their lack of concentration in high value at any particular locality. In most places the proportion of the platinum metals to the gold is very small. At one placer where large quantities of gravel were being handled the proportion of platinum to gold was about one-tenth of 1 per cent. by weight. In a few small operations the proportion of platinum was reported to be equal to the gold, and in still fewer it was reported to be more than the gold.

The problem of increasing the production of the platinum metals is closely involved with the production of placer gold and may be resolved into the problems of saving a larger proportion of platinum from the ground now mined and of finding new productive areas. California has been the best area in the world for developing methods of placer mining. The Golden Age of hydraulic and drift mining, however, has passed away. The method now in use, which handles the greatest quantity of gravel and saves the most gold, is dredging.

The platinum metals are generally supposed to be derived from the serpentine that occurs in many areas in northern California and southern Oregon. Wherever platinum seems to have been traced nearly to its source this rock is found. A roughness of the platinum and in some specimens a black or brownish coating, which is apparently iron oxide, indicate proximity to its source, but it has not yet been traced directly to the serpentine, although it is probably derived from this rock. The large areas of serpentine and related rocks in northwestern California and southwestern Oregon and the gold and platinum found in many of the streams that drain them make this country favorable for prospecting not only for the platinum metals, but for chromite, manganese, and cinnabar.

The possibility of increasing the production of the platinum metals, then, depends on improvements in the methods of saving now used, on the extension of these methods to areas that are known to contain these metals but that have not yet been mined, and on the discovery of new productive ground in northwestern California and southwestern Oregon, where the prospects seem to be good. Streams that carry insufficient gold and platinum to pay for mining at the prices formerly prevailing might now yield a profit. Streams that drain areas of serpentine would seem to be particularly favorable for prospecting. At no place are the platinum metals concentrated in large quantities. Being rarer than gold, they are harder to find than gold. Iridium is in great demand, and the fact that it forms 10 to 40 per cent. of the platinum metals in nearly all the placer deposits in the United States is a special incentive to the search for more of them. The risk that must be taken to find and develop new sources of supply is great, but the pressing need would seem to justify it.

The elimination of litigation and the equitable settlement of questions regarding surface rights and underground rights in drift mining and regarding the distribution of water for irrigation, power plants, and mining might also increase the output. The present price of the platinum metals, which is higher than that of gold, does its share in encouraging production.

Strength of Weld in Wrought-iron Pipe. ANON. (*The Gas Age,* vol. 41, No. 1, p. 36, January 1, 1918.)—Welded pipe made of wrought iron or steel is always subjected to a hydrostatic test before leaving the mill. The range of pressure applied in ordinary practice is from 250 pounds up to 2000 pounds per square inch, the great majority of sizes of standard weight pipe being tested under a pressure of 750 to 1000 pounds per square inch. As the hydrostatic test is an evenly applied bursting load of short duration, it does not insure against splitting of pipe at the weld under torsional, tearing, or compression stresses which are encountered in the course of cutting, threading, bending, and installing.

The strength or dependability of the weld in iron and steel pipe has sometimes been open to question, and as every pipe specialist knows from experience, new pipe may show a tendency to split under stresses apparently much below the hydrostatic test pressure. When the pipe is well made from a good grade of material, the percentage of such failures should become negligible, although they may not be entirely avoidable. In fact, lap-welded pipe should be especially reliable.

The subject has been quite thoroughly studied by pipe manufacturers for the purpose of improving their product. For example, in order to further minimize the percentage of weld failures, the A. M. Byers Company, of Pittsburgh, Pa., subjects all crop ends of pipe, the point where the greatest number of defects will naturally occur, to a crushing test.

A series of flattening tests on pipe, which had already been subjected to the mill tests referred to, have been carried out by Edward A. Klages, of the University of Pittsburgh. One hundred and sixty pieces of pipe of various sizes, both butt-weld and lap-weld, were tested, the pieces being placed at varying angles to the vertically applied pressure. Of the 160 pieces tested, including all sizes from 1 to 12 inches of different weights, only 12½ per cent. showed commencement of failure at the weld. In spite of the excellent welding quality of genuine wrought iron, for which this material has always been favorably known, the results of the tests were a little surprising in showing, in the main, less tendency to fracture at the weld than elsewhere, thus leading to the conclusion that the weld in genuine wrought-iron pipe is at least as strong as the body metal for a like application of stress. This was shown also by the fact that the position of the weld with respect to the applied load in flattening had no influence upon the location of the place of initial failure.

Decay in Wood in Buildings. ANON. (*Wood Preserving*, vol. 4, No. 4, p. 54, October–December, 1917.)—Much discussion during the past year occurred in the technical lumber press over the decay of wood in buildings. Several cases of bad failure were reported. Research was started by the Forest Products Laboratory at Madison, Wis., to determine the "killing points" in temperature and humidity of common fungi found in American buildings. These studies have already yielded data of considerable importance. It was found, for example, that with a temperature approximately 100° F., and a high humidity, the mycelia of certain fungi can be killed. This is contrary to a popular conception that methods of arresting growth of these fungi involve the use of hot dry air.

Field and laboratory studies indicate that much more care should be exercised in the selection of timber and in the construction of buildings to avoid conditions favorable to decay. A number of inspections of buildings which have given trouble on account of decay have shown that any one of the following causes may result in rapid deterioration of the building: (1) the use of green lumber; (2) allowing lumber to get wet during construction; (3) allowing the lumber to absorb moisture after the building is finished, because of leaks or lack of ventilation; (4) the use of lumber containing too much sapwood; (5) the use of lumber which has already started to decay. The avoidance of these conditions will, as a rule, prevent decay. In special cases, however, decay can be prevented only by preservative treatment. For this purpose salts, such as zinc chloride and sodium fluoride are recommended.

Melting Cast Iron in Crucibles. ANON. (*Graphite*, vol. 20, No. 2, pp. 4288 and 4290, February, 1918.)—It often happens that one must have an iron casting in such a hurry that in the time consumed to have the casting made in the ordinary way the use for the casting is almost over. Every one who operates a brass foundry but has no iron foundry can make iron castings quickly and cheaply in his crucible furnace, for he has all the equipment necessary for making these hurried important little iron-casting jobs, and the casting can be made almost before the pattern has reached the iron foundry.

Gray iron of the better kind melts at 2327° F., and, while this may appear to the brass founder to be a high heat compared with that for the yellow brass or composition metal he regularly melts, the melting is easily done in a graphite crucible, and is so simple that it is surprising that the practice is not more general. Alternate layers of charcoal and gray iron, broken to pieces about the size of walnuts or larger, are packed in a graphite crucible and melted in the pit brass furnace. An iron casting of high grade will be secured in a very little longer time than it takes to make a brass casting. The bottom of an old brass crucible may be used as a cover to keep out sulphur fumes and coal and hasten the melting.

The crucible melting of cast iron may also be carried on in a gas furnace. For the production and melting of aluminum alloys gas-heated furnaces are being employed that hold crucibles of 600 pounds' capacity when melting copper and approximately 200 pounds capacity for aluminum. In many instances cast iron is being melted in crucibles of 60 to 100 pounds' capacity for the production of high-grade castings; and, although the fuel costs are considerably higher than when using coke, the superior quality of the castings obtained more than justifies the extra fuel cost. In melting iron, about 700 cubic feet of artificial gas of a calorific value of 600 B. t. u.'s was required for each hundredweight of metal melted. The English hundredweight of 112 pounds is here indicated. From each crucible from seven to nine heats of iron were obtained.

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INDEX TO VOL. 185.

Aerial navigation, America's air service (Durand), 1

Air, Physics of the (Humphreys), 83, 359, 517, 611, 785

Alleman, Gellert, and Charles J. Darlington: Occluded gases in ferrous alloys, 161, 333, 461

Alloys, ferrous, Occluded gases in (Alleman and Darlington), 161, 333, 461

America's air service (Durand), 1

Bancroft, Wilder D.: Outline of colloid chemistry, 29, 199, 373

Berg, Eskil: Propulsion of ships, 317

Book Notices:

- Allen, Alfred H.: Commercial organic analysis, vol. 9, 846
- Dolt, M. L.: Chemical French, 728
- Fraps, G. S.: Principles of agricultural chemistry, 844
- Harrison Safety Boiler Works, Finding and stopping waste in modern boiler rooms, 575
- Maclean, H.: Lecithin and allied substances, 845
- Roebuck, John R.: The science and practice of photography, 843
- Rogers, Allen: Laboratory guide to industrial chemistry, 843
- Robertson, T. B.: The physical chemistry of the proteins, 846
- Society of Chemical Industry, Report on the progress of applied chemistry, vol. 1, 844
- Tieman, H. D.: The kiln drying of lumber, 292
- Villavecchia, V.: Treatise on applied analytical chemistry, 434

Brown, Lucius P.: Food wastes—some causes and remedies, 585

Camp sanitation (Mason), 731

Chemistry, Outline of colloid (Bancroft), 29, 199, 373

Coal supply, The problem of (Parker), 445

Colloid chemistry, Outline of (Bancroft), 29, 199, 373

Compton, Arthur H.: Non-molecular structure of solids, 745

Crooker, Slyvan J.: A graphical method for the construction of electrostatic fields, 131

Current Topics, 27, 28, 57, 58, 81, 82, 117, 118, 130, 135, 136, 140, 146, 153, 154, 198, 267, 268, 276, 281, 282, 294, 357, 358, 372, 387, 388, 415, 416, 419, 420, 435, 507, 508, 515, 516, 553, 554, 555, 556, 559, 560, 577, 578, 744, 774, 783, 784, 826, 831, 848–858

Darlington, Chas. J., and Gellert, Alleman: Occluded gases in ferrous alloys, 161, 333, 461

Differentiation, Mechanical (Elmendorf), 119

Differentiation, mechanical, Application to engineering problems (Elmendorf), 269

Dilution, Heats of (Pratt), 663

Durand, W. F.: America's air service, 1

Eastman Kodak Company, Research Laboratory Notes, 141, 277, 557, 711

Efficiency of light-production in organisms, The (Karrer), 775

Electric power transmission, Sag-temperature calculations of transmission lines on steep grades (Still), 509

Electron theory (Noyes), 59

Electrostatic fields, A graphical method for the construction of (Crooker), 131

Elmendorf, Armin: The application of mechanical differentiation to engineering problems, 269

Elmendorf, Armin: Mechanical differentiation, 119

Fairchild, David: The palate of civilized man and its influence on agriculture, 299

Food. The palate of civilized man and its influence on agriculture (Fairchild), 299

Food wastes—some causes and remedies (Brown), 585
Franklin Institute:
  Library Notes, 149, 289, 430, 571, 724, 842
  Members doing civilian work for the United States government, 423, 568, 718, 836
  Members who are in the active military or naval service of the United States, 421, 566, 716, 834
  Membership notes, 149, 288, 428, 571, 724, 841
  President's report, 284
  School, Annual report of the Director, 838
  Science and the Arts Committee Abstract of Proceedings of Meetings: December 5, 1917, 148; January 2, 1918, 287; February 6, 1918, 426; March 6, 1918, 570; April 3, 1918, 721; May 1, 1918, 838
  Sections, Proceedings of Meetings, 148, 287, 426, 570, 721
  Standing committees, 1918, 425
  Stated Meeting, Proceedings: December 19, 1917, 147; January 16, 1918, 283; February 20, 1918, 424; March 20, 1918, 565; April 17, 1918, 715; May 15, 1918, 833

Gases, occluded, in ferrous alloys (Alleman and Darlington), 161, 333, 461

Heat, A new principle in the flow of (Hering), 75
Heats of dilution (Pratt), 663
Hering, Carl: A new principle in the flow of heat, 75
Highways, Military (Page), 649
Humphreys, W. J.: Physics of the air, 83, 359, 517, 611, 785
Huse, K., and A. H. Nietz: The sensitometry of photographic intensification, 389

Jones, L. A., and R. B. Wilsey: The spectral selectivity of photographic deposits, 231

Karrer, E.: A neutral-tint and variable tint screen, 539
Karrer, Enoch: The efficiency of light-production in organisms, 775

Landau, David, and Percy H. Parr: A new theory of plate springs, 481
Leffmann, Henry: Permanence in photographic prints, 825

Mason, W. P.: Camp sanitation, 731
Massachusetts Institute of Technology, Electrical Engineering Department, Research Division Notes, 143, 417
Mechanical differentiation (Elmendorf), 119
Mechanical differentiation, Application of, to engineering problems (Elmendorf), 269
Military highways (Page), 649

Nela Research Laboratory Notes, 551, 707, 829
Neutral-tint and variable-tint screen (Karrer), 539
Nietz, A. H., and K. Huse: The sensitometry of photographic intensification, 389
Non-molecular structure of solids (Compton), 745
Noyes, William Albert: The Electron theory, 59

Occluded gases in ferrous alloys (Alleman and Darlington), 161, 333, 461
Organisms, The efficiency of light-production in (Karrer), 775

Page, Logan Waller: Military highways, 649
Palate of civilized man (Fairchild), 299
Parker, Edward W.: The problem of coal supply, 445
Parr, Percy H., and David Landau: A new theory of plate springs, 481
Photographic deposits, Spectral selectivity of (Jones and Wilsey), 231
Photographic intensification, The sensitometry of (Nietz and Huse), 389
Photographic prints, Permanence in (Leffmann), 825
Physics of the air (Humphreys), 83, 359, 517, 611, 785
Plate springs, A new theory of (Landau and Parr), 481
Pratt, Frank R.: Heats of dilution and their variations with temperature, 663

Prints, photographic, Permanence in (Leffmann), 825
Problem of coal supply (Parker), 445
Progress-of-work chart, An improved (Schlink), 697
Propulsion of ships (Berg), 317
Publications received, 152, 293, 435, 576, 729, 847

Sag-temperature calculations of transmission lines on steep grades (Still), 509
Sanitation, Camp (Mason), 731
SCHLINK, F. J.: An improved progress-of-work chart, 697
Screen, A neutral-tint and variable-tint (Karrer), 539
Sensitometry at photographic intensification (Nietz and Huse), 389
Ships, Propulsion of (Berg), 317
Solids, Non-molecular structure of (Compton), 745
Spectral selectivity of photographic deposits (Jones and Wilsey), 231
Springs, plate, A new theory of (Landau and Parr), 481
STILL, ALFRED: Sag-temperature calculations of transmission lines on steep grades, 509

United Gas Improvement Company, Physical Laboratory, Notes, 555
U. S. Bureau of Chemistry, Notes, 561
U. S. Bureau of Standards, Notes, 137, 409, 547, 703, 827

WILSEY, R. B., and L. A. JONES: The spectral selectivity of photographic deposits, 231

Vol. 185 JUNE, 1918 No. 6

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CONTENTS

Camp Sanitation 731
W. P. Mason

The Non-Molecular Structure of Solids 745
Arthur H. Compton

The Efficiency of Light-Production in Organisms 775
Enoch Karrer

Physics of the Air 785
W. J. Humphreys

Permanence in Photographic Prints 825
Henry Leffmann

Notes from the U. S. Bureau of Standards: 827
Comparative Tests of Chemical Glassware.

Notes from the Nela Research Laboratory: 829
The Visibility of Radiation.

The Franklin Institute: 833
Stated Meeting, May 15, 1918.
Members of The Franklin Institute Who Are in the Active Military or Naval Service of the United States Government or Are Doing Civilian Work for the Government.
Committee on Science and the Arts, Stated Meeting, May 1, 1918.
Annual Report of the Director of the School.
Membership Notes.
Library Notes.

Book Notices 843

Publications Received 847

Current Topics 744, 774, 783, 784, 826, 828, 831, 832, 848, 849

Index 859

Announcements . . . . ix-xiv

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INDEX TO ADVERTISERS

PROFESSIONAL CARDS, PAGES XVI AND XVII

PAGE
American Pulley Co., Third cover page
Bancroft & Brother, Insurance, Philadelphia xvi
Barnett, G. & H. Co., File Works, Philadelphia . . Fourth cover page
Bilgram Machine Works, The, Bevel Gears, Philadelphia xvii
Borden, John, & Bro. xvi
Borgner, Cyrus Co., Fire Bricks, etc., Philadelphia xv
Bradley Printing Co., Philadelphia . xvii
Chester Steel Castings Co., Philadelphia vii
Commercial Photo Engraving Co. . . xv
Ellis Adding-Typewriter Co. i
Fidelity Trust Co. xvi
FRANKLIN INSTITUTE, Alumni Association vi
FRANKLIN INSTITUTE, Awards of . . . . xii-xiii-xiv
FRANKLIN INSTITUTE, Certificate of Membership, Terms and Privileges xi
FRANKLIN INSTITUTE, Indices to Subject-matter and Authors . . . vi
FRANKLIN INSTITUTE, Officers and Trustees x
FRANKLIN INSTITUTE, JOURNALS for Sale vi
FRANKLIN INSTITUTE, School of Mechanic Arts vi
Hamlin & Morrison, Analytical Chemists, Philadelphia xvi
Keystone Screw Co. viii

PAGE
Leeds & Northrup Co., The, Electrical Measuring Instruments, Philadelphia iv
Lippincott, J. B. Company, Publishers . . . . iii, xviii
Lonergan, J. E. Co., Oilers, etc., Philadelphia vii
McCaffrey File Co. . Fourth cover page
Moore & White Co., The, Papermaking Machinery xvi
Nice, Eugene E., Mfr. of Paints, Varnishes, Fillers, etc. xvii
Oldach Company, Book-Binding . . iv
Olsen, Tinius, Testing Machine Co., Testing Machines and Hydraulic Presses vii
Philadelphia Book Co. xvii
Philadelphia Electric Co. xv
Phosphor Bronze Smelting Co., Phila. xvi
Powers - Weightman - Rosengarten Co., Chemists iv
Riehlé Bros. Testing Machine Co. . . xvi
Sadtler, Samuel P. & Son, Consulting Chemical Experts. xvii
Sellers, Wm. & Co., Inc., Machinists, Philadelphia v
Troemner, Henry, Scales vii
Underwood Typewriter Co. Fourth cover page
United Gas Improvement Co. ii
Watson & McDaniel Co., Philadelphia iv
Weber, F. & Co., Draughting and Engineering Instruments . . . xvii
Wiedersheim & Fairbanks, Patents . xvi
Wood, Alan, Iron and Steel Co. . . viii

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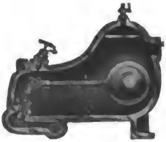

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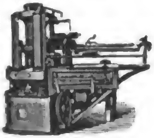

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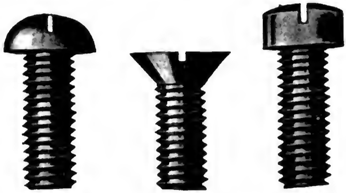

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SECTION MEETINGS. Thursday Evenings (except week of Institute Meeting), 8 o'clock. October 1 to April 30.

PAGE
Officers for 1918 x
Membership xi
Awards and Premiums xii
  The Franklin Medal
  Elliott Cresson Medal
  Potts and Longstreth Medals
  Certificate of Merit
  John Scott Legacy, Medal and Premium
  Boyden Premium
Journal and Indices vi
School of Mechanic Arts vi

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